Practical Clinical Ultrasonic Diagnosis

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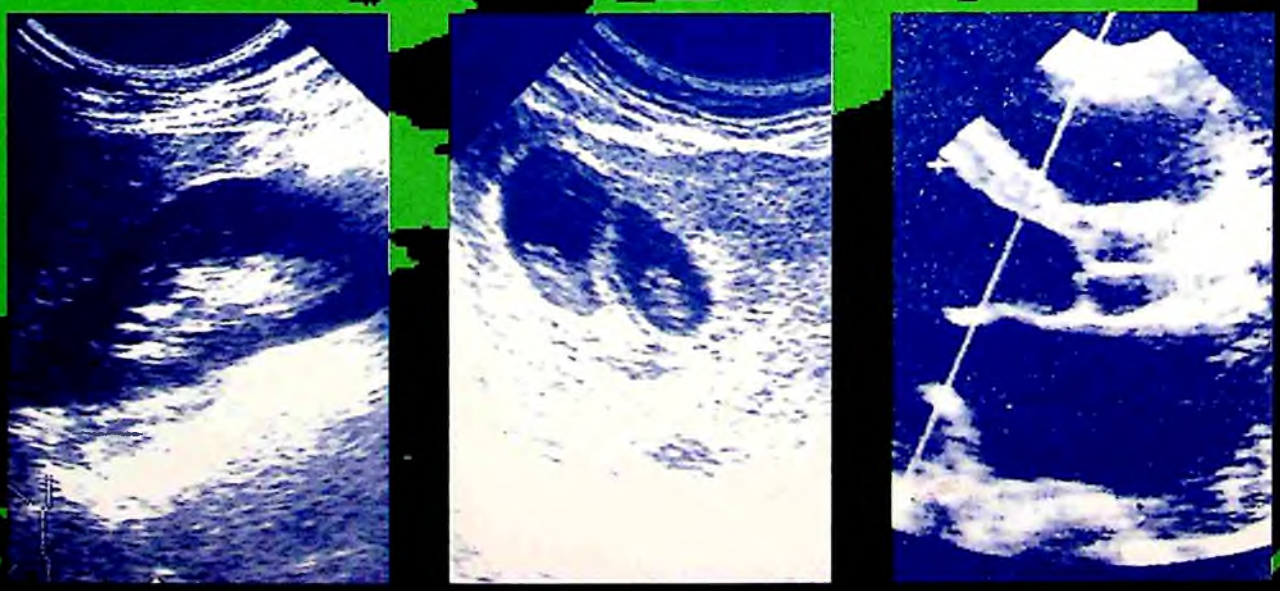
Lin Liwu



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Preface

In recent years, contemporary ultrasonic technology has been widely used in clinical medicine. It has acquired rapid development along with the continual development of ultrasonic engineering technology. The high resolution of real-time gray ultrasonic diagnostic apparatus was first used widely. Then, two-dimensional Color Doppler Flow imaging apparatus was gradually applied in clinics. The authors compiled this book, *Practical Clinical Ultrasonic Diagnosis*, base on their experiences and materials accumulated for many years in the clinical ultrasonic diagnosis of diseases of the liver, biliary system, pancreas, spleen, gastrointestinal system, kidneys, urethra, bladder, adrenal grand, prostate, scrotum, in the department of obstetrics and gynecology, heart and chest as well as in scientific research. The main contents of each part are briefly introduced as follows:

The first part (Chapters 1 to 3) is about the clinical diagnostic basis of ultrasound. It introduces mainly the diagnostic method of ultrasonic imaging. The instrument adjustment and the basic method of the ultrasonic imaging analytical diagnosis are also described. The common acoustic effect and the distinguishing of the ultrasonography pseudomorphism are introduced in greater detail. The contents also contain the physical basis of the ultrasonic diagnosis and ultrasonic imaging technology.

The second part (Chapters 4 to 15) describes the ultrasonic diagnosis of abdominal diseases. This is the focal point of the book. It makes a relatively systematic introduction of the anatomical outline of the abdominal organs, as well as the ultrasonic examination and diagnostic methods of common diseases. It stresses on the liver's ultrasonic anatomy, distinguishing of the pseudomorphism due to certain pseudofocuses in liver ultrasonography and the acoustic effect, and the ultrasonic diagnostic essentials of common liver space-occupying lesions, and diffuse lesion, as well as certain new concepts and new knowledge. Ultrasonic imaging not only accurately displays the abnormal phenomenon of gall bladder stones, tumor, precipitin, ascarid, etc., it also has an important effect in differential diagnosis of obstructive jaundice. It has a unique value in transcutaneous intrahepatic cholangiography, drainage, and cytological examination guided by ultrasound. It has great clinical significance in drainage decompression of acute biliary diseases. In this book, the methods of detection of the biliary tract and the ultrasonic imaging analytical diagnostic method of the diseases of biliary tract, such as the cause of the thickened gall bladder wall

and the characteristics of its images, the abnormal echo of the fossa of the gall bladder, and the cause of the dilation or constriction of the bile duct, are introduced as the focal items. The ultrasonographic characteristics of some diseases which are less commonly reported previously, such as perforation of the gall bladder, bile gas, cholestasis, etc., are well described here. Ultrasonic imaging, nowadays, is the ideal method used to diagnose pancreatic diseases. It can clearly display the pancreas, the pancreatic duct, the blood vessels and the nearby organs, and present more reliable data of pancreatic inflammation and space-occupying lesions. The authors mainly introduce the methods of detection of the head of the pancreas, tail of the pancreas, pancreatic duct, etc., and the analytical methods as well as pseudomorphic distinguishing method for some common abnormal pancreas.

The imaging characteristics and differential diagnosis of the carcinoma of the pancreas are also described in comparative detail. The book also introduces spleen ultrasonic imaging, spleen ultrasonic detective technique and the ultrasonographic display of splenectasis, splenic tumor, cyst of the spleen, splenic rupture and hemorrhage under the capsule, splenic abscess, sarcoidosis, congenital disease of the spleen and portal hypertension.

Ultrasonography can display the layers of gastrointestinal tract wall and the regions of lesions through drinking enough water or perfuse liquid. Nowadays, ultrasonic imaging may become one of the major methods used to diagnose diseases of the digestive tract, in the same way as fiberscope and X-ray examination. The authors place emphasis on the ultrasonic anatomy and detective technique of each part of the digestive tract, and the ultrasonographic characteristics of tumors at the inferior extremity of the esophagus, stomach, and intestine. They also introduce ultrasonographic manifestations of congenital hypertrophied pyloric stenosis, pylorochesis, acute gastric dilatation, intestinal obstruction, gastroenteric perforation, stone and foreign body in the stomach, and gastroenteritis. Diagnosis by transrectal endoscopic ultrasonography is also one of the main discussion topics in this chapter.

Ultrasonic diagnosis of the kidney, ureter, bladder, adrenal gland, prostate and scrotum are described from Chapters 10 to 14. It is known that their anatomic position and structure are favorable for applying ultrasonic imaging diagnosis. Ultrasonography can not only clearly display each part of the kidney, easily showing the structure and pathological changes of the kidney, such as the presence of a renal tumor, stone, tuberculosis, cyst, etc., without the use of any auxiliary drug, it can also overcome the limitations in the application of the X-ray and isotope. When endoscope examination or intravenous contrast examination cannot be performed because the lower urinary tract is obstructed or the kidney is seriously damaged, ultrasonic examination will appear to be much more important. Its values are as follow:

1. early diagnosis of renal tumors
2. differentiation and definition of the renal space-occupying lesion
3. diagnosis of all sorts of renal diseases and definition of their relationship with the nearby organs
4. ultrasonically-guided puncture to perform pyelograph or cytological and histological examinations
5. observation and monitoring of a transplanted kidney

The authors make a detailed introduction of the analytical methods of abnormal renal acoustic images. They also introduce ultrasonographic characteristics of the ureter stone,

congenital ureterocele, hydro-ureter, tumor of the ureter, and congenital anomaly of the ureter. The bladder is a hollow viscous. It has good acoustic transmission when it is filled with urine. So ultrasonic examination is the first means for detecting vesicle diseases. It has a much higher detective rate of tumors of the bladder. The limits which the tumor has infiltrated can be understood and it is of important in determining which stage the tumor is in. Ultrasonic examination has a very high specificity in the diagnosis of stones, foreign bodies and diverticulum of the bladder.

In this book the authors mainly introduce the detective method of the adrenal and the ultrasonographic characteristic of its common diseases. Ultrasonic imaging is of important practical value in understanding the size of the prostate, the limits and property of its pathological changes, its relation with the bladder, etc. Meanwhile, the authors also introduce the methods of detecting the prostate through the abdominal wall, rectum and perineum, and the ultrasonographic manifestations. They also introduce ultrasonographic characteristics of some common diseases of the prostate and the key points of the differential diagnosis. Ultrasonography can clearly display the structure of the scrotum. It has a comparatively high rate of diagnosing hydrocele testis, tumors and inflammation of the testis and epididymis, and enorchia. The degree of varicocele can be determined by Doppler.

The main contents of ultrasonic diagnosis of diseases of the abdominal wall and retroperitoneal diseases indicate the pathological essentials of the retroperitoneal diseases; the analytical method of the ultrasonic examination of the diseases of the abdominal wall and the retroperitoneal diseases, as well as the ultrasonographic manifestations and the key points of the ultrasonic diagnosis of common diseases such as inflammation and tumor of the abdominal wall, tubercular peritonitis, retroperitoneal cyst, abscess, tumor, lymphadenectasis and diseases of great vessels of the posterior abdominal wall, etc.

The third part (Chapters 16 to 17) is about ultrasonic diagnosis in the department of obstetrics and gynecology. Chapter 16 is about the ultrasonic diagnosis used in the obstetrical department. Firstly, the authors introduce maternal physiology in pregnancy related to ultrasound and the method of observation of the pregnant uterus. It includes general observed items which are the uterus, pregnancy cyst, fetal heart, placenta, fetal movement, fetal head, amniotic fluid and umbilical cord. It also includes specially observed items like the measurement and observation of the crown-rump length, occipitofrontal diameter, head circumference, transverse diameter of the abdomen and abdominal perimeter, transverse diameter of chest and chest circumference, anteroposterior diameter of the fetal liver, fetal kidney, the length of the fetal thighbone and fetal epiphysis ossifying center, and so on. Through this, growth of the fetus can be evaluated. Besides the contents above, the authors introduce the ultrasonographic characteristic of each duration of normal pregnancy and the ultrasonic diagnostic methods of common pathologic obstetrical department.

Chapter 17 is about the ultrasonic imaging diagnosis of diseases in the department of gynecology. The authors emphasize on the ultrasonic diagnostic analytical methods of gynecopathy and common diseases of the uterus and ovary. The book also studies the ultrasonographic characteristics and the key points of the ultrasonic differential diagnosis of non-nepotistic cyst of the ovary, cystic nepotistic tumor, parenchymatous tumor, etc. They briefly introduce the ultrasonographic characteristics of annexitis, pelvic abscess and tubal patent test by liquid instillation using B-mode ultrasound.

The fourth part (Chapters 18 to 19) is about ultrasonic imaging diagnosis of diseases of the heart and chest. The main content of this part is about the ultrasonic diagnosis of

angiocardiopathy. The authors stress on the basic principle, main points of operation, normal images, diagnostic methods and the clinical application value of the ultrasonic detective technique of the M-mode and B-mode echocardiogram, common cardiac acoustic contrast examination, Doppler echocardiogram, and so on. They briefly describe the manifestation and the main diagnostic points of each model of echocardiogram of common angiocardiopathy, such as rheumatic valvular heart disease, mistral valve prolapsed syndrome, rupture of mistral chordae tendency, cissecting aneurysm, cardiomyopathy, pericardial disease, infectious endocarditis, cardiac tumor, rupture of the sinus of Valsalva, common congenital heart disease, coronary heart disease and pulmonary heart disease.

The second section of part 4 is about ultrasonic diagnosis of thoracopathy. Its major value is in diagnosing the tumor of the chest wall and peripheral tumor of the lungs, observing the situation of the hydrothorax, diagnosing the space-occupying lesion of the mediastinum and observing its relation with the heart, performing the percutaneous puncture for cytological and histological examination of the tumor of chest wall and the peripheral tumor of the lungs and hydrothorax puncture drainage under the guidance of ultrasound. Ultrasonic detective methods and the ultrasonographic characteristics of thoracopathy are also the main topics of discussion in this chapter.

The last part (Chapter 20) mainly introduces the application of intervening ultrasonography in clinical diagnosis and treatment.

Besides the ultrasonic examination methods of each organ, the application of new technique, the clinical and pathological changes of common diseases and their ultrasonographies are also described in detail. There are more than 400 black and white photographs of typical images of all kinds of diseases in the book attached with line sketch maps. This enables clinical doctors and ultrasonic practitioners to combine the photos with the writing and so comprehend the content of the book easily.

Due to the rapid development of ultrasonic diagnosis technology, there may be some careless mistakes inside the book, and I hope fellow members of the same profession are willing help me point them out.

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Contents

Part 1

The Clinical Diagnostic Basis of Ultrasound

Chapter 1

The Physical Basis of Ultrasonic Diagnosis

1.1. THE FUNDAMENTAL CONCEPTS OF ULTRASONIC WAVES

1.1.1. Definition and Production of Ultrasonic Waves

A sound wave is a kind of wave transmitted by its vibration in an elastic medium. Vibration is caused when a body undergoes to and fro periodical movements about a definite position. The place where the vibration takes place is called the source of the vibration. An elastic body is a body which may produce reversible changes in its shape and volume when acted upon by an external force. The body to which vibration is transmitted is called the "medium". Vibrations can only be transmitted in an elastic medium. Sound waves with frequencies over twenty thousand Hz which are beyond the range of human hearing are called ultrasonic waves. An ultrasonic wave is a type of mechanical wave. The transducer (probe) of an ultrasonic appratus is based on the principle of reversible piezoelectric effect. The piezoelectric effect crystalline plate is fixed inside the probe. When it is subjected to a high frequency alternated electric field, it will change by compression/expansion in a definite direction. When the alternated electric frequency is over twenty thousand Hz, ultrasonic waves will be produced. On the other hand, the crystalline plate accepts ultrasonic signals. In accordance with the principle of positive piezoelectric effect, it can transform the sound energy of an echo into electrical signal. After the information is processed and displayed, the image will be shown on the screen.

1.1.2. The Period, Frequency, Amplitude, and Wavelength of Ultrasonic Waves

When an ultrasonic wave is transmitted through an elastic medium, the time taken for the particle to vibrate to and fro once is called the period (T). Within one unit time, the number of times required for the particle to complete its vibration is called the frequency (f) and its unit is circles/second or Hz. Therefore frequency is the reciprocal of the period, namely $f = 1/T$.

The frequency of a wave is determined by the frequency of the source of vibration. Currently, the commonly used frequency range for ultrasonic diagnostic apparatus is 2–10 MHz, with 3–5 MHz being the most common and with exceptional ones ranging up to 20 MHz.

When the ultrasonic wave is transmitted through a medium, vibration causes a particle to move by a certain distance. The short distance moved by the particles from the position of balance to maximum displacement position is called the amplitude (A). The amplitude is proportional to piezo (P), reciprocal to the density of medium (ρ), and reciprocal to the speed of sound (C) and the frequency of the vibration angle (Ω), namely,

$$A = \frac{P}{\omega\rho} .$$

The speed of sound is the distance traveled by the sound wave transmitted through a medium per unit time. The speed of sound varies in different media. The speed of sound in air is the lowest, 345 m/sec, followed by water, 1500 m/sec. In steel it can reach up to 5300 m/sec. The speed of sound in various tissues of the human body is also different. For example, it is 1400–1500 m/sec in muscles, 1476–1580 m/sec in fatty tissues, 1530 m/sec in the cerebrum, 1476 m/sec in the cerebellum, and in bone tissues, it reaches 3360 m/sec. The average speed of sound in soft human tissues (muscle, fat, blood, etc.) is 1540 m/sec.

Wavelength (λ) is the distance over which the sound wave is transmitted within a period, and is equal to the distance between two consecutive and similar points in the same phase. Its relationships with the frequency (f) and the speed of sound (C) is:

$$\lambda = \frac{c}{f} .$$

In clinical ultrasonic diagnosis, if the average value of the speed of sound in the human body is calculated as 1500 m/sec and the ultrasonic frequency is 2.5 MHz, the wavelength in human body will be

$$\lambda = \frac{c}{f} = \frac{1500 \text{ m/sec}}{2500000 \text{ Hz}} = \frac{1500000 \text{ mm/sec}}{2500000 \text{ Hz}} = 0.6 \text{ mm} .$$

If the ultrasonic frequency is 30000 Hz, the wavelength is 5 cm. Obviously, the wavelength of an ultrasonic wave at such a frequency is too long, and the resolving power is too low, which is not suitable for clinical diagnosis. The wavelength of an ultrasonic wave commonly used in diagnosis is less than 1 mm. This will guarantee the proper resolving power. In conclusion, ultrasonic waves with frequencies between 2–10 MHz are generally used.

1.2. ULTRASONOGRAPHIC TECHNIQUES

1.2.1. The Emission and Reception of Ultrasounds

The emission and reception of an ultrasonic wave is based on the principle of the crystal effect. When crystals, like natural quartz or artificial piezoelectric ceramics, come under the

action of external forces, an opposite charge will be produced on the intersurface. This is the positive piezoelectric effect. On the other hand, the crystal will experience a change in thickness if an electric pressure is applied to the intersurface. This produces a stretching and shrinking phenomena, resulting in vibrations which in turn generate sound waves. This is the negative piezoelectric effect. The transducer in ultrasound installations makes use of the negative piezoelectric effect to emit ultrasounds, and the positive piezoelectric effect to receive the electrical signal induced by echo sound pressure. At present, piezoelectric cyrstals in ultrasonic probes are mostly man-made piezoelectric ceramics. The essential components are barium titanate, aluminium, aluminium niobate magenesate, etc. Commonly used is a series of aluminium zirconate titanate. In recent years, piezoelectric film has been used. Its acoustic impedance is low and it closely resembles soft human tissues. The film is also flexible and can be coiled up.

1.2.2. The Principle of Ultrasonic Tomography

In optic imaging, because of the short wavelength of visible light, the general visible matter is larger than the wavelength of light. Therefore a large amount of light wave is reflected. As a result, an image will always be left behind on the hind side matter. Obviously, optic imaging will not reveal the internal structure of the matter, and only the surface image can be seen.

Sound wave imaging differs from optic imaging in many aspects. Sound frequency and wavelength are in the magnitude of tens of centimeters, even one or two metres. If the wavelength of a matter is shorter than that of sound, it will not act as a barrier to the transmission of the sound. The wavelength of the medical ultrasonic wave is about 10^{-4} m. It behaves like radiation, exhibiting directivity, reflection, refraction, transmission, and scattering. Many comparatively small objects can block the transmission of ultrasounds. Objects with wavelengths longer than that of ultrasound reflect the ultrasounds, while objects with shorter wavelengths allow it to pass through. Objects with a similar wavelength can scatter ultrasonic waves. Medical ultrasonic tomography works on the interaction between ultrasounds and biological tissues. In principle, medical ultrasonic imaging can be reflection imaging or sonotranslucent and scattering imaging. Currently, common medical ultrasonic imaging apparatus are based on the principle of pulsed echo technology, namely reflection imaging.

Ultrasonic imaging by utilizing a pulsed echo reflected wave is associated with special sound impedance of the medium. Specific sound impedance in normal tissues and pathologically changed tissues is different, so an abnormal boundary sound reflection may result. This phenomenon allows us to recognize an abnormality. Any ultrasonic medium will produce an image if there is internal mutation of the specific sound impedance. Therefore the ultrasound will form an image in the interior of a nontranslucent tissue. The parameter used for examination is sound pressure (sound amplitude). Therefore all ultrasonic transducers are sensitive to sound pressure. This is different from optic or X-ray imaging by using high intensity examination. Their S/N ratio is much higher. This is also one of the advantages of ultrasonic imaging.

When using an A mode examination to realize a B mode using tomography, the most remarkable difference, besides changing the A mode amplifier indicator to the B mode brightness indicator, is that we need to scan the object being examined by manual, mechanical, or electronic scanning with electronically controlled delayed emission.

1.2.3. The Gray Scale Technique

The gray scale technique in ultrasonography refers to the use of different grades of amplitude of echo in the image, by using black/white layers of echo respectively, to reflect the layers of gray scale, that is the degree of the grade of black/white. In general, the human eye can distinguish the degree of difference of black and white to about 10%, namely 1/10 of the difference of black and white. Gray scale of the 8–10 grades is distinguishable by the human eye. However, for maximum limitation to reflect the tiny difference of sound impedance, the more abundant grade of the gray scale is used clinically to display the layer of image in order to raise the quality of image. At present, the gray scale of ultrasonic equipment is in the range of grades 16–64, the lowest being not less than grade 8. The maximum is grade 256. Although the naked eye cannot discern the layers of the images, we get something similar to the actual tissue, which is useful in studying the structure of the tissue and any pathological changes.

1.2.4. Depth Gain Compensation (DGC)

As the ultrasonic wave is transmitted through a tissue, some energy is bound to be lost. Therefore the echo amplitude from deep tissues is much less than that from surface tissues nearer to the transducer. In general, an ultrasonic signal of 1 MHz transmitted a distance of 1 cm in vivo will produce an attenuation of 1 Decibel. For the purpose of displaying identical quality of images at both the deep and shallow positions, we must compensate the attenuation from the depth. The DGC circuit follows the time passed while the circuit of the gain of ultrasound is by logarithmic increase. It is also called the time gain compensation circuit (TGC). An ultrasonic wave transmitted through a tissue experiences energy loss in two ways: absorption and attenuation. Therefore when considering amplifying the gain, we must also take into account attenuation caused by a change in distance, and absorption.

1.2.5. The Resolution of Ultrasonographic Diagnosis

In ultrasonographic diagnosis, the ability to distinguish between two different tissues is called the resolution. This comprises the longitudinal resolution, transverse resolution and thickness resolution.

1.2.5.1. *Longitudinal Resolution*

This is also called axial resolution, distance resolution, or depth resolution. It is the ability to resolve the distance between two objects along the beam axial line, which is measured by the discernable distance between two objects. It is determined by the interval between the ultrasonic wavelength emitted and pulse. The wavelength of an ultrasonic wave is the theoretical limit of longitudinal resolution. If the distance between two objects is shorter than one wavelength, it cannot be discerned (Fig. 1.1). This is referred to as the sonolucent type. If it is the reflected type, the maximal theoretical resolution will not be smaller than half of a wavelength. But due to the complex nature of biological tissues, only 2–3 wavelengths are reached and not the value of theoretical resolution. Suppose the ultrasonic wave is 3 MHz

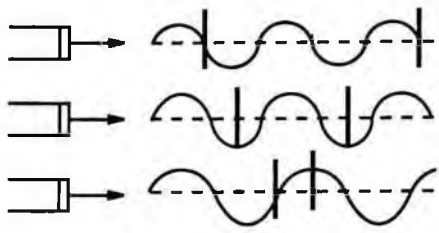

Fig. 1.1 The relationships between longitudinal resolution with wavelength. Upper figure: very good resolution. Middle figure: critical resolution. Lower figure: poor resolution.

and wavelength $\lambda = 0.5$ mm, the actual longitudinal resolution is about 1–1.5 mm. Obviously, by raising the frequency of the ultrasound, the resolution will be raised too, but if the frequency is too high, the requirement for penetration will not be met. Therefore we must, based on the requirement of examination, and within the ascertained range of penetration, raise the frequency of ultrasound accordingly. The longitudinal resolution of the more common equipment is 1–1.5 mm.

1.2.5.2. *Transverse Resolution*

This is also called the lateral resolution, horizontal resolution or location resolution. It refers to the ability to resolve the distance perpendicular and parallel to two points. It uses the distance between two objects which can just be resolved by the sound beam. It is therefore considered as the width of the beam (Fig. 1.2). Transverse resolution is the main parameter determining the quality of ultrasonographs. Good transverse resolution will produce refined images, and show minute structures. Otherwise the dots of the image will be coarse and appear as transverse strips. The width of a beam is determined by the diameter of sound source, the frequency of ultrasound, and the location far away from the sound source. It is chiefly determined by the size of the crystal in the transducer and the mode of its arrangement. The side lobe effect of an acoustic beam has a great influence on the near field resolution. Therefore, in general, the transverse resolution power is lower than the longitudinal resolution power. At the same time, since the beam scatters with an increase in distance, resulting in lower transverse resolution, a part of the volume effect is more marked. The transverse resolving power of a commonly used ultrasonic equipment is about 2 mm. The resolving power may be increased after focusing. Multiple crystal probes may have long axis

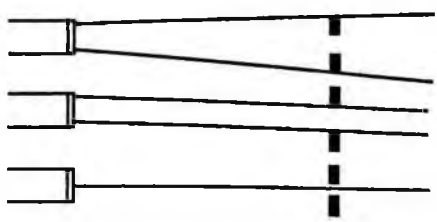

Fig. 1.2 The relationship between transverse resolution and the width of the sound beam. Upper figure: very good resolution. Middle figure: critical resolution. Lower figure: poor resolution.

transverse resolution and short axis resolution due to different forms of crystal and arrangement. In general, short axis transverse resolutions are poorer than long axis resolutions.

1.2.5.3. *Thickness Resolution*

The thickness of the beam in the direction of the thickness of the probe results in ultrasonic sectional images which are not very thin tomographic images, but rather thick overlapping images. The phenomenon is often seen in clinical analyses. It causes distortion of the images, and should not be overlooked.

Raising the frequency can improve transverse resolving power and longitudinal resolving power, but we must make sure that there is sufficient penetration. By using probes of different frequencies in accordance with the different positions for examination, and by various focusing techniques adopted by contemporary ultrasound, the resolution power will be greatly increased.

1.3. THE INSTALLATION AND MAINTENANCE OF ULTRASONOGRAPHY EQUIPMENT

1.3.1. Installation of Equipment

Nowadays, the most commonly used real time ultrasonography equipment are the mechanical sector type, electronic sector type (phased array), electronic linear array and convex array type. The types of equipment and installation are chosen in accordance with the necessity of daily clinical use. Before installation and operation of the apparatus, the instructions for using the apparatus must be read thoroughly in order to understand the fundamental structure and nature of the equipment and the requirements for installation and operation.

To install a set of ultrasonography equipment, the first consideration is finding the best spot. The floor of the room must be flat, not sloping. The room must be dry and well ventilated, without vibrations and disturbances from other electrical appliances. The environment should be dust–free. We must also remember to earth the equipment.

1.3.2. Utilization and Maintenance of Apparatus

1.3.2.1. *It Should Have a Stable Source of Voltage*

Before installation of the apparatus, the voltage must be ensured, particularly in areas where the source of voltage is not stable. A sudden change of voltage can damage the equipment and a low voltage can result in the malfunctioning of the cathode of the oscilloscope tube. A reliable electronic voltage stabilizer should be used and its power capacity should be higher than that needed by the equipment. In general, a capacity of around 1000 voltampere will be sufficient. If there is something wrong with the voltage stabilizer, it should be repaired immediately. Many units have experienced damage to the equipment due to a default in the

stabilizer. Before using the ultrasonography equipment, let the stabilizer run for 2–3 minutes. When the voltmeter indicates a stable voltage, start the machine.

1.3.2.2. *The Right Temperature*

The ultrasonography apparatus, especially the more sophisticated type, requires a specific working temperature range, generally between 10–35°C, but the best temperature is around 25°C. In very hot areas, air-conditioning should be provided. When air-conditioning is used, we must note the original high relative humidity. When the temperature is suddenly decreased to dew-point, the water droplets condensed on the components of the apparatus and the connecting wire board will cause a short circuit, damaging the electronic components. Hence the lowering of temperature must be done very slowly while keeping the air-conditioner running. It is best to decrease the relative humidity of the room before turning on the air-conditioner.

1.3.2.3. *The Right Humidity*

Ultrasonography equipment, like other sophisticated apparatus, requires a relative humidity of 30–90% in general. The optimal relative humidity is 70%. Higher relative humidity directly damages the electronic components. If condensation is found within or without the machine, or on the surface of the oscilloscope screen, the machine must not be operated. The atmosphere must be dehydrated before the machine is operated.

1.3.2.4. *Prevent Strong Illumination of Light*

Any strong illumination like solar light and fluorescent lamps can cause the fluorescent powder of oscilloscope screen to age quickly. This will darken the illumination. Other components like the probe wire and the camera lens should not be exposed to strong light either. The windows of the machine room should be shaded. After use, the whole machine should be covered with a light-shading cloth.

1.3.2.5. *Ventilation and Dustproofing*

The purpose of having good ventilation is to keep the air inside the machine room fresh, dry, and at the right temperature. However, the apparatus must also be protected from dust as dust accumulated in the equipment, especially at the filter, can cause defaults.

1.3.2.6. *Protection of the Probe*

The probe is a crucial part of the ultrasonography equipment. It has a great influence on the quality of image. Therefore great care should be taken to protect the probe. Except for specially designed ones, probes should not be immersed in liquid. The probes should not be steamed or sterilized. They should not be dropped or scrapped with a knife. The cable of the

probe is subjected to frequent bending, which can result in damage. While using it, we should not pull it by force or twist it too much.

1.3.2.7. *Continuous Operating Hours of the Apparatus*

Within a unit time, the machine should not be switched on too frequently to avoid shortening the life of the oscilloscope tube and the apparatus. In an environment with proper temperature and humidity, the machine can continue to work for 3–4 hours. Without air conditioning, after working for 2 hours, turn off the machine for 20–30 minutes to faciliate the radiation of heat to lower the temperature. Therefore, during daily use, it is preferable to concentrate the examination of the patients within a definite time period in order to increase the utilization rate of the apparatus within a unit time.

Chapter 2

Methods of Ultrasonic Imaging Clinical Diagnosis

2.1. THE SCOPE OF APPLICATION OF ULTRASONIC IMAGING DIAGNOSIS

From the physical nature of ultrasound, we can study the structure of different tissues in the human body which possess different acoustic impedance, thus forming numerous interfaces. This is the fundamental condition of ultrasonography and it may also be used to identify the structure of a tissue, organ, or lesion according to the condition of echo. In clinical diagnosis, the scope of application is as follows:

(a) Understanding the position, morphology, size, internal structure and the relation with surrounding tissues and organs of the human body, so that we can determine whether the tissue or organ is normal; for instance, to detect the enlargement or shrinkage of the liver, ptosis or ectopia of the kidney, and the presence of any deformity;
(b) Determining if there is a change in the histological morphology of the viscera, such as cirrhosis of the liver, variation of histological morphology inside the liver due to schistomiasis, or destructive changes in the intrarenal structure due to renal tuberculosis;
(c) Discovering space-occupying lesions of a tissue or organ, including benign and malignant space-occupying lesions, cystic or substantial lesions;
(d) Understanding the condition of various channels in the human body, such as whether the common bile duct is obstructed, the ureter is dilated, the gastrointestinal tract is blocked, and determining the condition of blood vessels;
(e) Discovering an abnormal structure of the viscera, such as gall bladder stone, urinary tract stone, calcified focus and fibrous nodules;
(f) Understanding the motility of the viscera, for instance, by using real-time ultrasound, to observe the valvular activity of the heart, respiratory movement, gastrointestinal peristalstic waves and fetal hearts;
(g) Applying ultrasound during operative treatment to observe small structures;
(h) Performing puncture under the guidance of ultrasound, needle puncture and drawing of focal tissue for cytological examination under the guidance of real-time

ultrasound, small needle cutting for cytological examination, or inserting a tube for drainage, radiological examination, and treatment;

(i) Application in implantation of viscera, such as implantation of the kidney and pancreas, to observe the change of the viscera implanted and its vitality;

(j) Observation of the development of the fetus.

2.2. ULTRASONIC IMAGING EXAMINATION

2.2.1. Adjustment of the Apparatus

2.2.1.1. *The Important Points of Standard Ultrasonography*

In order to get an accurate diagnosis, a clear image must first be made available for analytic observation. At this point in time, the structure of the apparatus should be adjusted. The requirements of a standard ultrasonograph should be

(a) A total well-proportioned image, with proper brightness and contrast.
(b) Fine and dense echogenic dots in the image and moderate strength of echo.
(c) Sufficient gray display,
(d) Minute structure and minute focus can be clearly displayed in the image.
(e) Every part of the tissue and deep tissue can be clearly displayed, making the outline of viscera complete and the echo at the shallow and deep parts uniform.

2.2.1.2. *Method of Actual Adjustment*

(a) Adjustment of brightness
The adjustment of brightness on screen usually takes as the standard the time when light grating just disappears. It should not be too bright, otherwise the structure of the tissue will not be clearly displayed and it is also not beneficial to the protection of ocillogram. On the other hand, it should not be too dim or the structure of the tissues will not be clearly displayed. Dim lighting will also cause eye fatigue.

(b) Adjustment of contrast
Like an ordinary TV, the adjustment of contrast should make the image clear, and minute signals should be clearly seen. It is correct when the echogenic dots in the image are generally rather fine.

(c) Select the working mode and proper probe well.

(d) Designing the gain of the apparatus
Adjustment of total gain can make the echogenic dots in total image dense or scarce. Repeated adjustment of total gain will make a certain focus which is not that clearly displayed become clear. If the total gain is too strong, it will cause coarse echogenic dots and lower the resolution of the minute structure. If the total gain is too weak, it will cause the image to be too dim and thus not displayed clearly. In general, after proper adjustment, it should be maintained within relative stability as far as possible in order to be beneficial for comparative analysis. At present, many ultrasonic imaging apparatus have displayed the gain figure in the image, so that it is convenient to make comparisons for every examination.

(e) Proper control of near suppression and far gain
Near (in general it refers to 1–4 cm) suppression control, also called near suppression, will lower the intensity of the echogenic dots which are too strong and which are inside the tissue near the probe, in order to resolve the structure of every layer clearly, hence making the image uniform. If it is well controlled, it will clearly display the subcutaneous connective tissue, shallow structure of the viscera and tissue, and shallow structure of the viscera and tissue of the superficial layer. The near gain switch will control the sensitivity of the ultrasonic reflection of the near field, with the range between 0––40 dB/cm. In general, for gain, the area beyond 8–10 cm is called the far field or far distance. Far gain is for compensation of the phenomenon of too weak echo at the far field of an image by absorption attenuation of ultrasound received by soft tissue of the human body. Its range is 0–6 dB/cm. Control far gain should be considered in relation to the frequency of the probe, the position of the viscera being examined, the contents and the constitution of the examinee (fat or lean) and other factors. If the frequency of the probe is 3 MHz, the far gain will be 3 dB/cm; if the frequency is 3.5 MHz, the far gain will be 3.5–4.0 dB/cm; if frequency is 5 MHz, the far gain will be 5.0 dB/cm. If we are examining the general solid viscera, the far gain will be 3–4 dB/cm. But if we are examining the posterior wall of the bladder or observing the prostate or uterus posterior to the bladder, the far gain should drop to 0–0.1 dB/cm. If it is an examination of the liver of a fat person, the far gain should be increased by 4–5 dB/cm.

(f) Adjustment of the focusing installation
Many up-to-date ultrasonic apparatus possess segmental focusing, namely near field, median field and far field focusing. To focus on superficial tissue, it refers to the area less than 4 cm away from the physical surface, a near field of 1 segment (N) of focusing is used in general. Another position may select median field (M) and far field (F1, F2) focusing according to the difference in depth. Proper application of focusing will make the outline or boundary of the focus or target clearer. Whole course focusing is segmental focusing by division of time. Under general frame frequency, for example when frame frequency is 30 f/s, the frame frequency of 1-segmental focusing is still 30 f/s, that of 2-segmental focusing is 15 f/s, that of 3-segmental focusing is 10 f/s, and that of segmental focusing is 7.5 f/s. If 3- or 4-segmental focusing is used at this moment, it will cause the floating phenomenon of the image. But under high frame frequency, no floating phenomenon or marked flicker phenomenon of the image is found for 1-, 2- and 3-, or even 4-segmental focusing.

(g) Control gray display
Under normal conditions, we should first select the whole course gray scale. For the representations of post disposal, we should first select the linear disposal mode as it will greatly reduce the lack of fidelity between the image and actual echo information. If special disposal is necessary for certain focus or target, we should then select the proper post-disposal mode to dispose the image according to the condition of the echo, so as to raise the resolution of the focus or target. That will be beneficial for the study of the nature of the lesion.

2.2.2. Preparation of the patient

For the purpose of obtaining an accurate diagnosis from ultrasonography, the sonogram should be made clear and resolvable in accordance with the fundamental principle of

ultrasonic imaging and the best conditions for imaging. The hollow viscera which are being examined should be fully filled with liquid and rid of the interference of gas. Therefore, preparatory procedure prior to examination is very important. All sorts of preparatory procedure should be done for the patient in accordance with the viscera being examined and the different positions. For instance, the examination of the gastric region should be done on an emptied stomach or after drinking a special liquid; for the examination of the uterus and the annex, the bladder should be moderately filled; the examination of the biliary tract system is usually done on an emptied stomach. Let the bile juice fill the gall bladder as it is beneficial for discovering lesions inside the gall bladder; if it is necessary to test the functioning of the gall bladder, a fatty meal should be consumed beforehand. All these should be made known to the patient in order to ensure better cooperation from him. Getting well prepared before the examination will enable satisfactory results to be obtained from one examination. If the bladder is empty during the examination of the uterus, or if examination of the gall bladder takes place after a full meal, accurate results cannot usually be obtained and the examination should be repeated. This is a problem that deserves attention.

2.2.3. Method of Examination

2.2.3.1. *Key Points of Ultrasonic Imaging Examination*

(a) Thoroughly expose the area of examination. Select the best sonolucent window;
(b) The place where the skin is in contact with the probe should be applied with a sufficient amount of gel. As much as possible, let the plane of the sound beam be perpendicular to the principal plane of the target being examined as much as possible in order to get clear images;
(c) Apply multiple-direction and multiple-angle examination in order to avoid misdiagnosis of small foci;
(d) Be sure of the relationship between the focus and the structure of the visceral anatomy for accurate localization;
(e) Undergo diagnosis by the combined methods of anatomial structure and functional variation, i.e undergo a combination of stastic and dynamics observation.

2.2.3.2. *Position of the Patient*

When doing ultrasonic imaging examination, the position of the patient is determined according to the viscera being examined and the location of focus. The purpose is to obtain better exposure to the position being examined and to get rid of interference in order to obtain a clear image. For instance, for the examination of the liver, the supine position is usually used though the semidecubitus position may also be used. But for the examination of the external margin of the right hepatic lobe, the left decubitus position is used. For the examination of the right posterior lobe of the liver, the prone position is often used. During the examination of the gall bladder, the patient may first take the supine position then put the right upper arm on the head to increase the width of the right intercostal space and the sonolucent window. Sometimes the left decubitus position is used to let the gall bladder shift a little to the left side, thus fully exposing it, in order to get a clear image. For the

examination of the pancreas, multiple body positions are used for displaying the head, body and tail of pancreas. If the decubitus position is used, we may let the gas from the gastrointestinal tract rise up, which is beneficial for the display of the pancreas. The sitting position may cause the liver to displace downwards, displaying the pancreas through the liver, while the prone position displays the tail of pancreas through the body. For the examination of the kidney, the supine, prone, upright, sitting and decubitus positions are also used.

2.2.3.3. *Mode and Method of Examination*

The accuracy of the ultrasonic imaging diagnosis and the quality of the image is directly connected to the method of examination. Besides being familiar with the anatomy of the viscera being examined, attention should also be paid to manual training. As much as possible, select a proper section during examination to let the focus and target be fully exposed. Also get rid of and avoid the embarassment of acoustic passage as much as possible by getting rid of the rib and gastrointestinal gas. The general procedure and fundamental manipulation are as follows:

(a) Examination by order
This is the fundamental method of ultrasonic imaging diagnosis. It is usually done according to the landmark of the physical surface, or by special anatomical landmark of the viscera. Examination is systematically done by longitudinal, transverse or oblique section in order to form typical sectional images of the viscera. For instance, in order to display typical longitudinal, transverse and oblique sectional images using a crisscross network of longitudinal and transverse sections, the liver is examined through the longitudinal section of the abdominal aorta, inferior vena cava, gall bladder, and mid hepatic vein, and through a series of transverse sections from the diaphragm dome of the liver to the interior margin of the liver, and through the oblique section of the portal vein at the subcostal border and hepatic vein.

(b) Examination by swinging sector
This method is usually done during an examination by order. When an imaging plane is selected, the position of the probe is not changed and the probe is inclined to make the section swing. By changing the angle between the probe and physical surface in order, sonograms within a three-dimensional section will be obtained. Images of deep structure in a rather big range may be displayed, and the viscera and focus will be fully understood. This method is more effective when the sonolucent window is narrow.

(c) Examination by parallel sliding
Move the probe from one end to the other end in parallel, such as sliding from the head to tail of pancreas for examination so as not to miss what an intermittent examination may miss out, particularly a small focus.

(d) Examination by turning the body position to the side
Changing the body position can usually change the sonolucent window, making the viscera or target fully exposed. In accordance with the condition of displacement of the viscera and target examined and the change of content, the focus can be found and the nature of the lesion can be determined. For instance, on the left decubitus position, the liver shifts downwards and to the left, which is beneficial to subcostal examination. Redundant growth inside the gall bladder will not move with changes in the body position, but the gall bladder stone will move.

(e) Examination at upright and decubitus position
By this examination, the range and tension of displacement of the viscera can be understood. It is the fundamental method for diagnosis of ptosis of the viscera. It is also beneficial for the examination of a small amount of fluid accumulated in the body cavity.

(f) Examination by rotation
This is the main examination method to identify the structure of the whole body by taking a target at a certain section as the rotational axis to display its continuous images at real time. It is actually the continuous examination to display the transitional time between the longitudinal, transverse and oblique sections. It plays an important role in the space localization of the focus and target to ascertain the relationship between the focus and viscera.

(g) Examination by crisscross central localization
This method is mainly used for ultrasonic localization and puncture under the guidance of ultrasound. This method is done by using two probes perpendicular to each other to get two images perpendicular to each other. The focus or target displayed by these two images are in the center of the images. At this time, the cross point of the imaging planes by the probe, crossed twice on the physical surface, will be the reference point of projection of the physical surface of the centre of the focus or target. But when undergoing localization for puncture, attention should be paid to the angle and depth of the inserted needle to avoid deviation and failure of puncturing.

(h) Examination by dynamic observation
By making use of the movement of the viscera inside the body, dynamic observation is done. For instance, by using respiration, the tissue, organ and focus which are covered by the ribs will be displayed. By making use of respiration, let the portion covered by the ribs be displaced to the intercostal space to the sound beam. At the same time, for exposure, it can help to determine whether there is adhesion or free accumulation of fluid. In addition, drinking water and eating fatty meals are helpful in identifying the structure of certain viscera and in understanding the conditions of functional change.

In doing ultrasonic imaging examination on certain viscera or targets, proper modes of examination and manipulation are adopted, or several methods can be used together. Different directions and angles are used for different individuals and viscera. It should be mastered flexibly. A three-dimensional conception from numerous images should be obtained and accurate determination of the localization and nature should be done. Also, some typical images for recording a file should be selected by means of videotape, drawing and photography.

2.3. THE FUNDAMENTAL METHOD OF ANALYTICAL DIAGNOSIS OF ULTRASONOGRAPH

2.3.1. Standard and Description of Localization of Ultrasograph

2.3.1.1. *Standard of Localization of Ultrasonograph*

The standard of localization often used nowadays are as follows:

Cross section (the direction of the probe facing left):
The left side of the image represents the structure of the right side of the human body; the right side of the image represents the structure of the left side of the human body; the upper part of the image represents the structure of superficial body wall of the human body; the lower part of the image represents the structure of the deep portion far away from the probe.

Logitudinal section (the direction of the probe facing upward):
The left side of the image represents the structure of the cephalic end of the human body; the right side of the image represents the structure of the pedal end of the human body.

Oblique section:
The standard of localization may be based on the standard of the cross-section or longitudinal section. The standard logitudinal section is taken if the oblique section is approaching the longitudinal section. Actually, it may be summarized thus: the left portion of the image is the section of the anterior part of the probe and the right portion of the image is the section of the posterior part of the probe.

2.3.1.2. *Description of the Special Features of Ultrasonography*

An ultrasonic imaging sectional echogram is also called a sonogram. Display by the technique of modulation of brightness is applied. Most sonographs of up-to-date ultrasound apparatus poses abundant gray so the structure of tissue displayed is rich in lamination and is clear. But the principle of distinction is still on the different degree of brightness, i.e, the degree of brightness on the ultrasonograph is identical to the strength of the echo. The stronger the echo, the brighter the image; the weaker the echo, the more gray and dim is the image. Accordingly, due to the different nature of the viscera and focus examined, the strength of the echo and the expression of the ultrasonogram are also different. The special features are described as follows:

(a) Description of the strength of the echo
Echo signals are divided into high echo (or strong echo), median echo, low-level echo, and echoless according to the degree of grayness of the ultrasongram. Whether the echo is strong, weak, high or low level usually depends on the normal echo of the viscera as a standard. Or it can be determined by comparing the focal echo with the strength of the echo of the surrounding viscera. For instance, the strength of the liver echo in cirrhosis of the liver is markedly higher than that in a normal liver. But the strength of the echo of a liver tumor may be strong, equal or low depending on the nature of the tumor.

(b) Description of the morphology of images
In accordance with the morphology of the ultrasonogram and the strength of the echo, we may have the following description:

Description of the bright portion of ultrasonograph:

(i) Hyperechogenic area: it usually refers to one whose diameter is bigger than 1 cm with the bright portion clear in outline and rounded.

(ii) Echogenic spot: it usually refers to an irregular bright portion with a diameter above 0.5 cm. The outline is clear or hazzy and the brightness may be even or uneven.

(iii) Echogenic dots: it usually refers to bright position smaller than 0.5 cm. The echo shows dot–like distribution with unidentical form, size and clearness; those with diameters less than 0.3 cm are usually small echogenic dots, and those less than 0.1 cm are minute echogenic dots.

(iv) Echogenic band: the bright portion is strip-like or band-like. Its thickness, length and evenness are all not identical.

(v) Echogenic ring: the bright portion by the arrangment of echogenic dots representing a circle.

Description of the gray portion of the ultrasonogram:

(i) Dark area: the local brightness of a sonogram is lower than that of the surrounding normal tissue. In general, a region whose diameter is over 1 cm may be called a dark area. According to the strength of the echo, it is further divided into low-level echo dark area and echoless dark area. After raising the gain, the echo of the former will be enhanced or many echogenic dots will be seen. The latter appears gray without any or with very few echogenic dots. In the case of bile juice and urine, after raising the gain, the strength of echo is not enhanced. No enhogenic dots are seen. The echogenic dots in the low-level echo dark area usually do not move with changes in body position. This area may also be called the substantial dark area. These dots are mostly seen in tumors or inflammatory parenchymal lesions. If the echogenic dots in the dark area can move with changes in the body position, that area is called the liquified dark area, such as in liquefaction of a tumor or abscess.

(ii) Dark circle: circular distributed dark band in the sonogram at the surroundings of the substantial tumor mass. It is also called dark halo or acoustic halo.

(iii) Silent zone: low-level echo or echoless gray dark strip band in the sonogram, such as a blood vessel and the biliary tract.

(c) Description of other features:

The internal echo is the echo formed by minute structures inside the viscera or focus. The echo posterior to the viscera or focus reflects in certain degrees the internal condition of the tissue. For example, if the focus of a tissue is liquefied, its posterior echo is stronger than that of the surrounding tissues. This is called the "echo enhancement effect". When the interface of the focus has rather strong reflections and attenuations, its posterior echo becomes weak or even disappears, this is called the "acoustic shadow". When the plane of a sound beam passing through acoustic impedance is greater than the tissue structure of the complicated interface, the image is bright at the superficial portion of sonogram while the image in the deep part is gray, dark and unclear. This is called "attenuation". In addition, the phenomenon induced by the acoustic effect has "margin drop off", "secondary echo" and "ascites effect". Certain sonograms are described as an image according to the image feature. For example, the sonogram of a mixed-up tumor mass formed by the tumor in the gastrointestinal tract is similar to the

image of a section of the kidney, and this is called the "pseudo-kidney sign". The image of a dilated common bile duct parallel to the lumen of the portal vein and their inner calibre are similar, and is called "the sign of double-barrelled gun". The sonogram formed by the metastatic carcinoma of liver, with its center having a strong echo encircled by a thick dark ring is called the "bull's eye sign".

2.3.2. The Principle and Important Points of Analytical Diagnosis of Ultrasonograph

Ultrasonic imaging is the organic combination of many branches of science, such as ultrasonic technology, radar technology, computer technology and the technology of image processing. The basic requirements in the field of medical diagnosis are systematic anatomy, regional anatomy, physiology, macropathology, internal medicine, surgergy, gynecology, obstetrics, pediatrics, opthalomology, and other basic medical knowledge as well as fundamental knowledge of electronics related to engineering design, ultrasonics, computer, image processing and the methods of operation and use of the apparatus. Therefore, ultrasonic diagnosis closely link the principles of ultrasonic physics and medical foundations with clinical knowledge in order to increase the rate of accuracy of ultrasonic diagnosis. Principally, it uses real time imaging to undergo dynamic and overall observation, and combines with the necessary measurement analysis.

2.3.2.1. *Principles of Analytical Diagnosis*

(a) Clear images should be selected for analysis.
(b) It should be understood that an acoustic image is not identical to an actual section of the tissue. The image is formed by acoustic impedance difference, by echo message produced by the acoustic impedance difference at the interface of the structure of the tissue. The image is subjected to the interference of all influent factors, and lacks fidelity.
(c) The sonogram reflects the acoustic feature of the structure of the tissue to a certain degree. It may infer the physical and pathological nature of the lesion, but different lesions may have similar acoustic features, so great precaution should be taken during diagnosis.
(d) Sonographic diagnosis is based on the expressions of morphology. Its basis is the morphological change of pathological anatomy, and the changes of pathological physiology.
(e) Certain functional tests may be used to discover and diagnose changes in morphological structure. For instance, after a fatty meal, the increased secretion of bile juice will cause more bile juice to flow into the originally not well-drained biliary tract. This is leads to a further dilation of the common bile duct. The causes and positions of obstruction can then be discovered and diagnosed. By measuring the cardiac function, we can evaluate changes in the dynamics of cardiac blood flow.
(f) Many artifacts in ultrasonic examination should be noted, such as a "secondary echo", "volume effect", "side lobe effect", drop out, interference of noise and attenuation and other acoustic effects. Multiple-section examination should be conducted with repeated verification in order to avoid the error of recognition.

(g) Sonographic analysis, combined with clinical and other technological data, should undergo comprehensive analysis and judgement in order to improve the accuracy of ultrasonic diagnosis.

(h) The problems of measurement of many diameter lines should be handled flexibly because biological statistics are relatively accurate and the individual variations are very obvious. Therefore, certain normal values should be given due attention, yet the individual conditions must be considered, particularly in the case of anatomical abnormality, which undergoes concrete analysis. Actually, in sonograph diagnosis, the morphological structures and functional variations play a determinative role.

(i) Follow up re-examinations is often practiced in sonograph diagnosis. The elapse interval is dependent on each case. If it is a chronic disease or a disease without much change, the interval between re-examinations may be suitably lengthened; if the disease is complicated or changes greatly, the interval may be shortened. Due to the uncertainty of the original sonograms of many diseases and insufficient preparation of the conditions prior to examination, diagnosis is difficult. As a result, we usually get an affirmative or negative diagnosis during the follow up re-examinations.

(j) The change in the physiological functions of certain viscera should be noted. For instance, with the advancement of age, the parenchymal portion of certain viscera may shrink, such as the thickness of the pancreas; certain organs such as the prostate may enlarge and certain channels may increase their width; some visceral tissue may be absorbed to form cysts, for example liver and kidney cysts which are often seen in the elderly. Certain viscera develop periodical changes such as the size of the ovaries, growth and variation of the follicle and lutein in the menstrual cycle of females, and the variation of the endometrium of the uterus during pregnancy. All these are factors which should be considered during an ultrasonic imaging analytical diagnosis.

2.3.2.2. *Important Points of Diagnosis*

(a) Analysis in accordance with the echo of the marginal outline of the viscera or focus is determined by the outlook of the tissue, the dimension of the outline from the echo, and by the characteristics of the boundary echo to determine the nature of tissue. If a mass has a boundary echo and the margin is smooth, it often indicates that the mass has a complete capsule. If there is no boundary echo and the margin is irregular, it is often an infiltrative lesion. In sonograph diagnosis, the relation between the viscera or focus with its surroundings should be noted, for example, the carcinomatous tissues of the liver usually press on the portal vein. The anatomical position should be relied on to pin-point the position of the viscera or focus and at the same time, to identify the nature of the target by the "acoustic shadow" and "enhancement effect", which are posterior to the focus or viscera.

(b) Analysis in accordance with the expression of the internal echo strength of the echo indicates the degree of difference of acoustic impedance of the tissue. A benign lesion usually has median or strong echoes and a malignant lesion has low-level echoes. But for the lesions of different viscera, the echoes are not identical. For instance, the primary carcinoma of liver may have sonograms showing strong echoes, equal echoes and low-level echoes. Renal carcinoma usually has low-level echoes. The coarseness and uniformity of the echoes are not identical in different viscera. The echogenic dots are

evenly distributed in the internal parts of the spleen, but poorly distributed in the liver. The brightness produced by the coarse structure has different bright spots and its distribution is uneven, while the brightness produced by the fine structure has similar bright spots, and even distribution. Echoes of cirrhosis of the liver show marked unevenness; the brightness of the light spot is much more uneven than in normal liver tissue. Malignant tumors often display echoes of different coarseness with uneven light spots.

During the observation of internal echoes, the variation of the channel inside the viscera should be noticed. Stones at the lower segment of the common bile duct or carcinoma of the pancreas head will cause dilatation of the gall bladder or bile duct. Obstruction of the ureter will cause dilatation of the renal pelvis. The variation of the structure and morphology inside the viscera is the main basis of diagnosis of diseases by sonograms.

In addition, while observing the internal echoes, different attenuation induced by different features of the tissue should be noticed. When doing a comparison of the attenuation of images, the gain and position of examination should first be fixed. The echo of tissues with hard texture or the superficial part of focus is strong and its posterior attenuation is increased. However, for tissues with a soft texture, the surface echo is weak and its posterior attenuation is decreased. Under normal conditions, there is great attenuation with fibrous tissues and less attenuation with fatty tissues. Under pathological conditions, a strong echo appears at the surface of the calcified area and its interior has a hazy acoustic shadow due to great attenuation. The surface echo of a benign lesion often has median strength and its posterior attenuation is ordinary. The surface echo of a malignant lesion is usually strong and its posterior attenuation is also great. For example, the primary giant mass carcinoma of the liver has strong echoes at the position of the lesion and marked attenuation at its posterior.

(c) In accordance with the results of functional tests, sonograms may be used for the functional test on an organ. For example, when measuring the volume of the urinary bladder and residual urine, ultrasound is painless although its accuracy is poorer than catheterization, and urinary tract infection by catheterization can be avoided. It is particularly suitable for repeated examinations of residual urine during the obstruction of the lower urinary tract and in neurogenic cystitis. The size of the gall bladder can be measured before and after a fatty meal, in order to evaluate the contractive function of the gall bladder. The important value of examination of the cardiac function is known to everybody. By means of the above-mentioned functional test, more information about the diagnosis of diseases will be provided.

(d) Under the guidance of ultrasound, needle puncture to aspirate material for cytological examination, needle aspiration, or small needle cutting for histological examination can be widely used in order to get the purpose of pathological diagnosis, for example, percutaneous liver puncture for the cytological examination or small needle cutting for histological examination, percutaneous per hepatobiliary tract puncture for drainage and cytological examination, percutaneous pancreas puncture for histological examination and puncturing focus for cytological or histological examination.

(e) Intraoperative ultrasound is used. For a small focus in the deep part and intracranial focus, we usually use a sterilized special ultrasonic probe for further examination as it is beneficial to the understanding of localization and nature of the small focus. It is also helpful in ascertaining the surgical area and scope.

2.3.3. Sonogram Features of Several Common Pathological Structures

2.3.3.1. *Sonogram of Inflammatory Tissue*

Early symptoms of acute inflammation is mainly edema and congestion, therefore, the localized expression is that the echoes become weaker and sonolucence is ehnanced. There is swelling and enlargement of the viscera or tissue, as well as exusion and necrosis of small areas, leading to increment of the interface and enhancement of echo and disorder. In the case of chronic inflammation, the fibrous tissues increase during the course of repair. The sonogram shows more disordered, increased and enhanced echoes. The distribution is remarkably uneven and its boundary echoes are often irregular or have unclear boundaries.

2.3.3.2. *Sonogram of Liquified Tissues*

If the liquified tissue is a clear fluid, a "without interface area" appears in the fluid. There are no echoes in this area, even if the sensitivity is increased. Clinically, it is called "echo-free area" or "liquified dark area". If the liquified tissue is a turbid fluid, a "less interface area" will appear in this area. This means that in this area, small echogenic dots may be found floating (and which may be fully distributed in this area) or precipitated at the bottom. If the body position is changed, small floating echogenic dots in this area will turn over or rise up, which is a positive sign of the shifting of gravity. Clinically, this is called the "turbid fluid dark area". If the liquified tissue is a thick abscess or any other necrotic tissues, echogenic dots with echoes of uneven coarseness and cord-like or band-like reflected bodies may be found in this area. In the sonogram we may find distribution by layers, which is also a sign of the shifting gravity. It is worthwhile to point out that the internal margin of the pyogenic area is usually irregular between the margin and the normal tissues. We may find a circle of "gray scale decreasing by ladder" area, which came about when the strong echoes turned to normal echoes. This is also a characteristic of the sonogram of a pyogenic fluid tissue.

2.3.3.3 *Sonogram of a Fibrous Lesion*

Many chronic inflammation and degenerative lesion tissues often undergo fibrous changes. According to the pathology, the degree of change may be divided into:

(a) Isolated fibrosis with dot-like distribution
The sonographic expression is an increase in the coarseness of the echogenic dots and its uneven distribution, for example in the cirrhosis of the liver;

(b) Many dot-like fibrosis are connected to one another
The sonographic expression is a cord-like or band-like echo enhancement band, such as in chronic cholangitis;

(c) Fibrosis with a network distribution
For example, in schistosomomiasis of the liver, the fibrous area inside the liver tissue is network-like. The sonographic expression shows a map-like or network-like echo enhancement area;

(d) Fibrosis presenting a patch-like distribution
If cirrhosis of the liver occurs, it is mainly due to the intrahepatic nodule being path-like during nodular cirrhosis. The echoes present a patch-like enhancement area whose

boundary is not clear. The size varies from 0.3–1.5 cm. Patch echoes may also reach several centimeters and the distribution is not even.

2.3.3.4. *Sonogram of a Calcified Lesion*

Certain viscera in the human body may often have calcified tissues. Due to the density and velocity of sound, the calcified tissues are markedly greater than normal tissues, the interface echo is markedly enhanced, thus causing the echo at the anterior margin of the calcified tissue to be very strong and relief-like. Due to excessive reflection of sound energy and the attenuation of sound being markedly higher than that of normal tissues, the distribution of sound energy posterior to the calcified tissues is very low. In the sonogram, a typical "acoustic shadow" appears. The expressions of stone and skeletal tissue in the sonogram are similar to that of calcified tissues.

2.3.3.5. *Sonogram of Gas*

Certain viscera in the human body such as the lung and gastrointestinal tract contain a lot of gas. Because the velocity of sound and density of gas is much lower than that of soft tissues, the interface reflection is the strongest — 99% of the ultrasonic waves are reflected back. The brightness of the interface is also extremely strong. In the sonogram, one may find very strong gaseous echoes. Also, since the coefficient of attenuation of gas is the greatest, the sound energy at its posterior is markedly decreased and a perpendicular acoustic shadow may appear. However, the gas is full of circulatory changes. In the sonogram, strong flickering hyperechogenic masses may vary with the peristalsis of the viscera, respiratory movements, or changes in the body positions. At the same time, its boundary is often hazy, unclear, or unstable. At its posterior, we may sometimes find star-tail signs moving swiftly past and that is quite different from the strong echoes and acoustic shadows of calcified tissues. This is the important characteristic used to distinguish between the two.

2.3.3.6. *Sonogram of a Tumor or Redundant Growth*

The sonogram of a tumor and redundunt growth are mainly expressed as variational characteristics of a space-occupying lesion.

(a) Certain localized margins of the viscera are regular, bulge out or may even protude irregularly. For example, the liver tumor protrudes from the margin, while in the case of a renal tumor, the outline of kidney is found to be bulging outwards.
(b) Internal structure of the viscera has been changed, oppressed, or displaced. For example, the tumor of the hilus of the liver often presses on or displaces the portal vein carcinoma of the pancreas head and also often presses on the pancreatic duct, causing dilation of the distal pancreatic duct.
(c) Marginal echo of a tumor or redundunt growth: whether it is clear or hazy, whether the capsule is displayed and if there is an acoustic halo, light wheel, carb-like extension or satellite-like distribution. The primary carcinoma of the liver often has an irregularly-

shaped or crab-like extension. Its surrounding often has sound halos, its anterior has light wheels, and there is a small modular satellite distribution.

(d) Internal echoes of a tumor and redundant growth tissues change greatly. According to pathological changes, they may be divided into strong echoes, equal echoes, low-level echoes, and mixed echoes. Also, they may present images of special morphology, such as metastatic carcinoma of the liver which presents the image of a bull's eye or a target. Internal echoes of a malignant tumor are often uneven or are accompanied by liquefaction, but internal echoes of a benign tumor are often even.

(e) The relationship between a tumor or redundant growth tissues with the surrounding viscera: Outward-growing tumors or redundant growths with a rather large volume often oppress the surrounding organs or cause infiltrative growth to a nearby organ. For example, the hilus of the liver often oppresses and even metastasizes to the inferior vena cava, forming embolic tumors inside the lumen; the tumor in the posterior wall of the stomach usually infiltrates the pancreas.

(f) Condition of far-distance metastasis of tumor: Malignant tumors usually metastasize to viscera far away. Not only do the carcinoma of the lung and digestive tract metastasize easily to the liver, ovarian cystadenoma also often metastasizes to the liver. In addition, the hilus of the liver and the lymphnode at the sides of the abdominal aorta are also good places for metastatis.

(g) Changes in the whole body: During the middle and late stages of a malignant tumor, accumulation of fluid in the body cavity often occurs, such as an ascites, hydrothorax, or pericardial effusion.

2.3.4. Identification of Common Acoustic Effect and Ultrasonograph

In clinical ultrasonic imaging diagnosis, the artifact of images is often caused by acoustic effects and other factors. The forms are different, leading to difficulty in diagnosing the ultrasonograph, or mistaking the artifact of the image for certain lesions or tissues, and so make the wrong conclusions. The cause of the artifact of an image is mostly related to the characteristics of the physics of ultrasound. Another cause is related to the poor nature of the apparatus, improper modulation, and unskillful manipulation. Still, a small part is related to the physiological or pathological conditions of the human body. Increasing the ability to identify all artifacts in the ultrasonograph is very important, and it is also a problem that an ultrasonic worker should understand.

2.3.4.1. *Reverberation Effect*

The reverberation effect is due to multiple reflection or repeated reflection of sound waves. Intrinsic vibration of free attenuation stimulated by a sound source and scattering induced by the uneven nature of the medium are all factors which will induce the reverberation effect. It is expressed as a gradual, orderly weakening of the image with identical signals. Its effect on the image is determined by the strength of the echo and the distance between the interface and the transducer. The greater the difference between the acoustic impedance of the interface, the stronger the reflection, the closer the separation, the higher the frequency and concentration of multiple reflection — these lead to a greater influential effect on the image. Therefore, multiple reflection of near field may cause the image of a lower level echo

at its back to be covered, or a false image to be formed in its interior. For example, multiple reflection of the abdominal wall during ascites may be mistaken for the thickening of the peritoneum. Sometimes, a normal multiple reflection of the abdominal wall will cover the focus at the anterior wall of bladder and cause misdiagnosis. Sometimes strip-like strong echoes in the common bile duct can be mistaken for ascarids. The method to overcome this is by means of proper suppression of the strength of the near field echo or by applying the water sac method in order to avoid imaging at the near field. We may also change the direction and angle of the plane of the sound beam to let the multiple reflection disappear.

2.3.4.2. *Artifact Induced by Acoustic Shadow or Elimination of Acoustic Shadow*

Due to local acoustic impedance and too big an acoustic impedance, the ultrasonic waves are completely reflected, absorbed and attenuated. At its posterior is a complete echoless dark area. For example, posterior to the stone or calcified tissues, we may find a perpendicular echoless area closely connected to the posterior of strong echogenic dots or hyperechogenic masses; this is the important basis for the diagnosis of stones and calcified tissues. But in small stones (diameter < 2–3 mm), there are often no acoustic shadows at the back and they appear as artifacts, and so wrong diagnoses may be made. This is an artifact of the image formed by the diffraction effect, leading to failure in using the strength of echo at the posterior of focus as the index to judge the attenuation of the echo of the focus. Therefore the examination of the small focus should be observed from many directions.

2.3.4.3. *Acoustic Shadow of Boundary Refraction*

This is a "false acoustic shadow" because it is not due to attenuation. It is also called the non-attenuation acoustic shadow, usually inferior to two lateral presenting a perpendicular acoustic shadow marginal angle. Sometimes it may be mistaken and thought to be caused by a gall stone. It is the artifact of the image caused by refraction, hence due attention should be paid to it.

2.3.4.4. *Margin Drop-Out*

Because the sound beam is nearly parallel to the interface, the sound waves reflect backwards or outwards. When the sound beam is nearly parallel to the lateral wall of the cystic lesion, the echoes cannot return back to the point where the source of sound is emitted. Hence the image of the lateral wall cannot be displayed and an echoless dark area, called the "margin drop-out", is formed. This phenomenon is often seen during the examination of the cystic tumor or gall bladder. By changing the angle of examination, this phenomenon can be eradicated.

2.3.4.5. *Posterior Wall Enhancement Effect*

Seen at the far-side interface of a structure with high sonolucent tissue, it is most obvious at the posterior wall of the cyst. The echoes are greatly enhanced. This is called the Posterior Wall Enhancement Effect. Due to refraction and difference in densities, the sound beam

posterior to the cystic construction is focused inwards, while the sound beam posterior to the solid structure spreads outwards, i.e. when the sound beam from the first medium strikes the second medium, and if the velocity of sound of the first medium is greater than that of the second medium, the posterior sound beam will be concentrated inwards, otherwise it will spread outwards.

2.3.4.6. *Artifact of the Image Due to Distortion*

Sound velocity varies with different tissues in the human body; when the sound beam passes through many layers of medium with different sound velocities, it will produce many declinations, thus forming a broken line and not a straight line. But on the echo screen it is always arranged in a straight line and an echo signal is obtained from the segments of the broken lines, thus distortion of the image is caused.

2.3.4.7. *After Vibration, or Ringing-Artifact*

Somewhere along the sound beams, there is a flat thin interface and below it is a thin layer of gas with a strong reflection coefficient, and it will easily produce a ringing artifact. It is due to sound energy being reflected many times between the flat, thin interface and the thin layer of gas, thus leading to a gradual attenuation of sound energy and a decrease in the amplitude, just like the case of sunlight passing through small holes of a dense cloud and then striking the ground. During the examination of the lung and gastrointestinal tract, such a phenomenon may occur. When examining a patient with "bile duct gas", a cord-like strong echogenic band may be found along the bile duct, and at its posterior is a perpendicular light beam striking the liver tissues, which will flicker with movement of the gas, particularly when the body position is changed. With this, the gall stone can be differentiated. In a sonogram it is called the "star tail sign".

2.3.4.8. *Artifact of the Side Lobe Effect*

Besides the main lobe in the sound source, there are several pairs of side lobes, in which the sound amplitude produced by the first side lobe is the biggest — about 20% of the main lobe. This side lobe is located at between ±10°–20° of the sound axis of the main lobe. When the main lobe of a sound beam is in the process of examining a matter, the side lobes are undergoing examination at the same time. The echoes from both overlap, leading to the production of hazy images and artifacts. For example, when the bladder is filled, shallow arc-like lines may be found superior to the posterior margin of the bladder, or the echoes of two overlapping bladders may be displayed. Actually, examination of all big interfaces will produce side lobe artifacts.

2.3.4.9. *Artifact of the Partial Volume Effect*

Since ultrasound is not an ideal geometrical fine line but a columna sound beam, namely, ultrasound beam possesses thickness, the echo information received occupies a definite space echo. Strictly speaking, a sonogram is the flattening of a three-dimensional space signal

image. The effect whereby the signal induced by the sound beam volume is more than the ideal section is called the Partial Volume Effect. Particularly in the non-focusing area, the thickness of the sound beam may reach several millimeters or even above 1 cm. Therefore, the piece of tissue "cut" by the sound beam is not very thin. If there is a focus cut by the sound beam with a diameter smaller than the thickness of the section, the sonogram will show overlapping images of the echo of the focal area and the echo of the focal surroundings, which leads to the structure of the image being mixed up and causes misdiagnosis. For example, fine echogenic dots appear in the small dark area, so the echoless dark area is mistaken for turbid fluid or a solid area, or gaseous strong echoes of the duodenum appear in the longitudinal section of the gall bladder's dark area, and hence, due to the presence of the acoustic shadows at its posterior, it is misdiagnosed as a gallbaldder stone. But the artifacts caused by the volume effect may be eliminated by changing the body position and the direction of the probe.

2.3.4.10. *Artifact by Concealed Attenuation*

Behind the tissues with a complicated interface such as in the inferior of many fibrous tissues, ligaments and scar tissues, the image cannot be displayed well and is easily misdiagnosed as the minute structure because of too much absorption of sound energy, causing weak illumination of sound energy at its inferior and weakening the echoes in this area. In particular, at the inferior of the big stone, calcified focus or skeleton, attenuation is more obvious; there is less sound energy so it is easier to induce artifacts by concealed attenuation. The minute lesion of the liver tissues, posterior to the serious fatty liver, must be examined carefully, otherwise the diagnosis may be easily missed.

2.3.4.11. *Artifact of Concealed Disappearance Induced by Gas*

A great decrease in sound energy caused by weak illumination is called Concealed Disappearance. This phenomenon occurs often at the inferior of a rather thick layer of gas. In general, the reflection coefficient between the gas and soft tissue is around 99.95%, while the sound attenuation of the gas itself is the greatest. Together, strong reflection and marked attenuation cause the viscera inferior to the gas layer and focal tissues to be completely concealed since no sound energy can be transmitted. If the gastrointestinal tract is filled with gas, it is usually impossible to display the pancreatic tissues or the focus posterior to it. Therefore, the conditions must be changed, for instance, by drinking large amounts of water or by repeating the examination to overcome the artifact caused by concealed disappearance.

2.3.4.12. *Artifact Due to Suspension Particle Effect*

This is often seen in rather thick liquified material such as an old blood clot or stasis of bile juice. In normal examinations of the gain, or when the gain is rather large, the many minute, even or uneven echogenic dots inside the dark area are often misdiagnosed as solid low-level echo tumors, such as the ovarian chocolate cyst. In the cardiovascular cavity, interface reflection is produced due to the ejection function of fluid. Minute echo signals may also be

produced. This is even more obvious when whirl flow is formed after blood flow passes through the constricted orifice, or when blood flow is slow during portal hypertension.

2.3.4.13. *Artifact by Ascites Effect*

Ascites, often seen in ultrasounic examinations, produce many kinds of acoustic effects. For example, the multiple reflections of the anterior wall of the abdomen may be mistaken for the thickening of the peritoneum and diagnosed as peritoritis. Some ascites have good sonolucence and cause strong reflections on the interface of its posterior medium. The image is bright and the echogenic dots increase in coarseness. For example, in ascites in the normal liver, echogenic dots increase in coarseness, just as in cirrhosis of the liver; the increase in thickness of the gall bladder and intestinal walls may be mistaken for edema of the gall bladder wall or chronic cholecystitis. Hence, at this moment in time, we combine the history and condition of the liver surface, the possibility of the portal vein being dilated, and the spleen being enlarged, for differential diagnosis.

2.3.4.14. *Artifact by Diaphragm Effect*

This may be seen during the examination of the liver under the right costal. When the probe is examining the superior-posterior region, an image similar to the liver echo is often found at the superior part of the bright diaphragm echo. The causes may be due to:

(a) multiple echoes;
(b) the concave surface of the diaphragm causing the direction of the echo to be changed, hence delaying the arrival to the non-responsible crystal and causing the imaging to cross over or shift over. The artifact is often mistaken for a lesion on the diaphragm. By changing the direction and angle of the probe, the image will change or disappear.

2.3.4.15. *Artifact by the Human Body of Measurement of Distance*

In general, ultrasonic measurement of the interval distance of the human body structure is rather accurate. Due to variation in the velocity of sound between the interfaces, errors can occur between the measured value and reality. An artifact of longitudinal measurement of interval is determined by the difference between sound velocity and the average sound velocity of soft tissues (1540 m/s). Transverse distance-measuring artifact is often due to refraction and is also related to the variation of sound velocity between interfaces. In addition, it is related to the nature of the design of the apparatus and probe. During puncture, under the guidance of ultrasound, this phenomenon should be given special attention, particularly when localizing the puncture for minute channel in the deep region, so as to avoid error of localization and failure of puncture.

2.3.4.16. *Gain Control Artifact*

As mentioned above, improper modulation of the gain will cause the image to lack fidelity, e.g. too low a gain will cause the target display to be larger. Therefore, there should be proper control of the gain according to the requirements of the examination.

2.3.4.17. *Dynamic Variation Artifact*

Physiological variation of certain biological tissues sometimes induce error during ultrasonic diagnoses. For example, the margin of the gestatin sac is blurred on the 12th week, and the fetal head is not yet clear; yet on the 13th week, the fetal head is clearly displayed; on the 24th week the placenta is near the internal orifice of the uterine cervix, and may be diagnosed as a low-positional placenta or paratial previa. But along with the stages of pregnancy, the placenta gradually rises and moves away from the internal orifice of the uterine cervix. With continuous observations, any misdiagnosis prior to the 24th week may be corrected.

In brief, when ultrasound passes through the human body, many variations occur on the interface due to the human body serving as a biological medium for sound transmission, and being a moving organic body. There are hence many factors affecting the transmission of ultrasound. Transmission of ultrasound in the human body is by a nonlinear parameter mode. Under the influence of physical factors in the course of transmission, many artifacts mentioned above may be produced. Three influential factors may be classified:

(a) Physical factors of ultrasound which influence its transmission in the human body, such as sound frequency, intensity, velocity and a series of factors during transmission;
(b) Factors of the tissue interface itself;
(c) Factors of the apparatus itself. The probe and all parameters of the main apparatus will affect the quality and fidelity of the image. From the above description, we know artifacts in ultrasonograph are always present, and the modes of expression are abundant and complicated. They must be identified during examination and careful observations must be made in order to avoid misdiagnosis.

The methods to overcome the artifact of the ultrasonograph:

(a) Repeat observations of the image
Using different angles, directions, and body positions during examination. If no image reappears, the possibility of the echo being produced by an artifact is high; if a false echo is produced inside the gall bladder due to the partial volume effect, it will disappear once the examination is changed;
(b) Carefully observe the variation of the characteristics of the viscera structure
If it is an artifact echo, there will be no variations in the tissues or the structure of the organ's interior;
(c) Re-examination after changing physiological condition
An emptied stomach, drinking water, passing urine and consuming fatty meals are examples that will alter the physiological conditions for re-examination. It often causes the artifact to disappear;
(d) Right control of the apparatus
During examination, if an artifact echo is suspected, we may adjust the gain or near field suppression and far field rises. In this way, ordinary artifacts will disappear after sensitivity is changed;
(e) Closely combine with clinical and other examination data
Since ultrasonographs lack specification, the tendency to blindly depend on ultrasonographs for making diagnosis must be overcome. In making diagnostic analyes,

it should be closely combined with the anatomical characteristics, pathological, physiological, and clinical data and other examination techniques, such as X-ray, CT, isotope and biochemical examinations. In this way, misdiagnosis of the images produced by artifact will be greatly decreased.

Therefore, strengthening the understanding of the basis of ultrasound, mastering the features of ultrasound, and combining ultrasound with clinical data are the main methods used to eliminate misdiagnosis produced by ultrasonic artifacts.

Chapter 3

General Description of the Gross Anatomy and Division of the Abdomen

Ultrasonographic diagnosis is conducted by ultrasonography to display the morphological change in human structures and the condition of internal structures. Therefore, while undergoing ultrasonographic diagnosis on the abdominal viscera, we have to be familiar with the anatomy of the abdominal viscera and their inter-relationship, and combine the structural morphology of the viscera revealed by ultrasonography with the actual anatomical structures. It is only after mastering the knowledge of the anatomy of the abdominal viscera that one can better manipulate the ultrasonographic diagnostic technique on the abdominal viscera.

3.1. ANATOMY OF THE ABDOMINAL WALL AND ABDOMINAL CAVITY

The abdominal cavity, referring to the abdominal pelvic, is a cavity formed by the skeletal frame, joints, ligaments, muscles and fasciae. It is longitudinally-flattened and has a round shape, with the longitudinal diameter beginning from the 5th intercostal space on top, down to the base of the pelvic. The longitudinal diameter is the longest and the transverse diameter is about 5 cm only. The upper part of the abdominal cavity is the diaphragm, which protrudes upwards, and the lower part is the pelvic diaphragm. The posterior wall of the upper abdominal cavity is the lumbar vertebrae with the psoas major and the quadratus lumborum on both sides. The rectus abdominis is in the middle of the anterior wall, with three pairs of flattened muscles on both sides (the external oblique, internal oblique, and transversus abdominis are arranged in increasing depth). Above the landmark of the pelvis is the abdominal cavity proper (called abdominal cavity for short). Below the landmark of the pelvis is the pelvic cavity.

3.1.1. The Layers of Abdominal Walls and the Peritoneal Cavity

3.1.1.1. *Anterior Abdominal Wall*

There are 6 layers from the outside to the inside: Skin, subcutaneous tissues, muscular layers, transverse fascia, extrapeioneal fat, and the parietal layer of the peritoneum.

3.1.1.2. *Posterior Wall*

There are 5 layers from the outside to the inside: Skin, subcutaneous tissues, lumbodorsal faseia, muscular layers, and retroperitoneal fat.

3.1.1.3. *Peritoneum and Peritoneal Cavity*

The peritoneum is comprised of 2 layers: the parietal layer of the peritoneum which is in close contact with the inner surface of the abdominal wall; and the visceral layer, which is in contact with the surface of the viscera. The parietal and visceral layers of the peritoneum are mutually transitioned to from a potential serous sae, called the peritoneal cavity (clinically, it is usually known as the abdominal cavity). There is a small amount of serous fluid inside the cavity, which has the function of lubrication. According to different coverings of the viscera by the peritoneum, the relation between the viscera and the peritoneum can be divided into three groups: Inner-position of the peritoneum such as gastrointestinal tracts, meso-position of the peritoneum such as liver, spleen, gall bladder, and urinary bladder, outer-position of the peritoneum (or called retroperitoneum) such as pancreas and kidneys.

3.1.1.4. *Abdominal Viscera*

The abdominal viscera can be divided into two groups. One group comprises the viscera in pairs, such as the kidneys, suprarenal glands, and ovaries. They have no mesentery at the origin of development, so the kidneys and suprarenal glands are extraperitoneal throughout. The other group comprises unpaired viscera, such as the gastrointestinal tracts, liver, gall bladder, pancreas and spleen. They have mesentery at the beginning of their development: During the development of the peritoneum, the transposition of the stomach and intestines, and the displacement of the viscera, cause the inner, meso, and outer position of the peritoneum to be distinguished. The viscera at the inner position of the peritoneum has two layers attached to the abdominal wall or their nearby viscera. In the middle of the two layers of peritoneum, there are arteries, veins, lymphatics (nodes), and nerves related to respective viscera. Different names are called by the different viscera attached, such as the omentum, which is associated with the stomach, the mesentery, which is associated with the intestinal tracts, and the ligaments, which are associated with the other viscera (like the liver) or abdominal wall. The general description of the anatomy of the abdominal viscera and their cross-sections are described in detail under ultrasonic diagnosis of various viscera.

3.1.2. The Division of the Peritoneal Cavity

The abdominal cavity can be divided into two major divisions by the transverse colon and its mensentery. The two divisions are the supracolonic and the infracolonic division (Fig. 3.1).

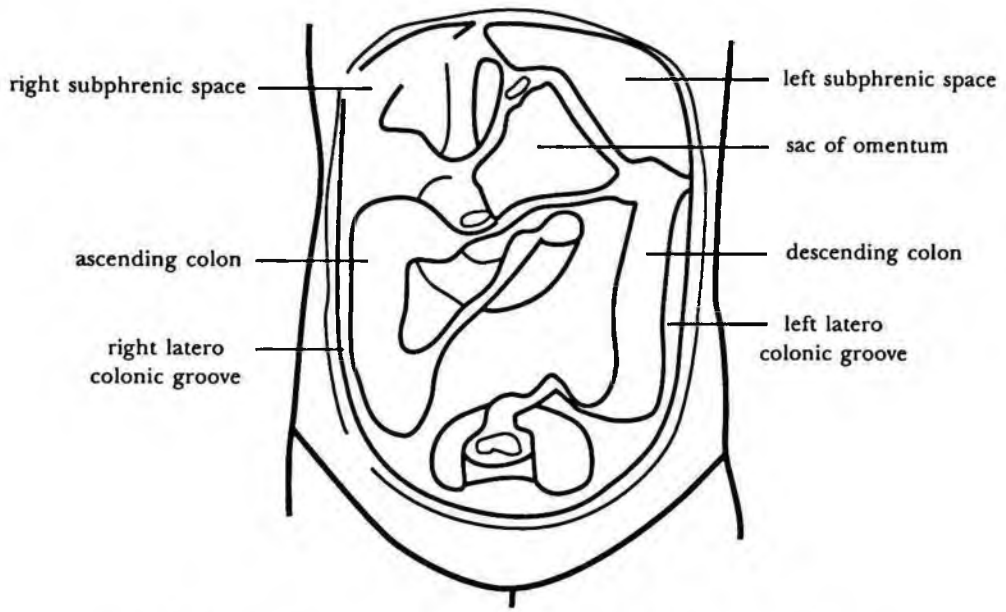

Fig. 3.1 Sketch map of the anatomy of the abdominal cavity.

3.1.2.1. *Supracolonic Division*

This is in the space between the diaphragm, the transverse colon and its mesentery. It is the region where abscess formation and accumulation of fluid take place easily. Several smaller divisions can be made by the ligament of the liver and the omentum minus. The following are the main parts:

(A) Sac of omentum
It is at the posterior of the omentum minus and the stomach. It links to the big peritoneal cavity through the foramen of the omentum located at the posterior of the hepatic-duodenal ligament. Ascites were first found to accumulate here.

(B) Subphrenic Space
This is the space located between the diaphragm and the liver and it is further divided into the left and right subphrenic spaces by the falciform ligament of the liver. There is a splenic ligament at the splenic flexure of the colon which prevents the fluid in the left subphrenic space from flowing into the infracolonic region.

(C) Hepatic-Renal Fessa
It is the space between the liver, right kidney, and the hepatic flexure of the colon. In

the supine position, this is the lowest position of the peritoneal cavity above the landmark of the supracolonic region.

3.1.2.2. *Infracolonic Region*

This is the peritoneal cavity below the transverse colon and its mesentery. It is partly covered by the omentum. The space is divided into four sections by the root of mesentery, the ascending and descending colon, namely the left and right latero-colonic groove, and the left and right mesenteric sinus. The right latero-colonic groove lies on the lateral side of the ascending colon and caecum, linking upwards to the hepate-renal fessa and downwards to the pelvic cavity. The right mesenteric sinus lies in the middle of the ascending colon and the root of mesentery. Here the fluid does not overflow easily. The left mesenteric sinus lies on the right side of the descending colon and from here the fluid may flow down to the pelvis.

3.2. GENERAL DESCRIPTION OF THE ANATOMY OF THE BIG BLOOD VESSELS IN THE ABDOMEN

Contemporary ultrasonographic techniques can reveal the abdominal aorta, inferior vena cava, portal vein and its main branches clearly. By sectioning the ultrasonic images, the position, size, morphological structure, swelling, and twisting due to the pathological changes of the big blood vessels at the posterior wall of abdomen can be clearly illustrated. Therefore with a thorough understanding of the anatomical characteristics, it is not only possible to diagnose pathological changes of the big blood vessels of the abdomen, but more importantly, many cross sections of the blood vessels can be used as localized landmarks for ultrasonography of the abdominal viscera and focal lesion. For instance, by observing the portal vein system, we can obtain valuable data about the diagnosis and treatment of liver diseases. The illustration of blood vessels surrounding the pancreas may be evidence of the localization of the pancreas and its pathological change. By observing the blood vessels of the abdomen, we may understand the pathological change in the tissues and viscera surrounding the blood vessels, and the condition of the growth of a tumor. Hence, familarizing oneself with the anatomy of the big blood vessels of the abdomen and their main branches is indispensable for ultrasonographic diagnosis of the abdomen.

3.2.1. The Abdominal Aorta and Its Main Branches

The abdominal aorta lies on the left anterior of the vertebral column. The thoracic aorta continues downwards and enters into the abdominal cavity, through the abdominal aorta foramen at the diaphragm, to form the abdominal aorta. It divides into the left and right common iliac artery at about the level of the 4th and 5th lumbar vertebrae. The position of abdominal aorta near the diaphragm is the deepest and the calibre is the thickest. It continues downwards and its position is also along the anterior to the vertebral column, becoming superficial gradually as it approaches the abdominal wall. Its lumen constricts regularly. Its main branches are discussed in the following section.

3.2.1.1. *Celiac Artery*

It emerges from the ventro-side of the abdominal aorta at the 12th thoracic or the 1st lumbar vertebra. This artery is short and thick, about 1–2 cm. It runs between the liver and pancreas, being the first visceral branch of the abdominal aorta after entering the diaphragm. It divides into left and right branches to form the splenic and hepatic artery. Therefore its cross section is represented by a "y" shape structure. The other branch, the left gastric artery, is rather small. It emerges from the ventro side of the celiac artery, obliquely towards the left upper region.

3.2.1.2. *Mesenteric Superior Artery*

It is the second unpaired visceral branch of the abdominal aorta. It emerges from the ventro-side, 1–2 cm lower than the celiac artery. It descends downwards in front of the left renal vein, passing through the posterior of the pancreatic vein and the head of the pancreas. It crosses the uncinate process of the pancreas and the anterior of the third portion of the duodenum to enter the mesentery, and is nearly parallel to the abdominal aorta. Some people have their mesenteric superior artery closely connected to the celiac artery, sometimes even sharing an opening at the abdominal aorta.

3.2.1.3. *Renal Artery*

It is the paired branch of the abdominal aorta, emerging about 2 cm lower to the mesenteric superior from both sides of the abdominal aorta. Its physical surface projection is somewhat lower than the level of the pylorus, at about the level of the 1st lumbar vertebra or between the 1st and 2nd lumbar vertebrae. Somewhat towards the upper lateral region, the left renal artery is rather short, it turns towards the posterior and lateral sides to enter the hilus of the kidney. Sometimes it may cross over at the level of the pylorus. The right renal artery is longer. It goes along the vertebral column, turns right, crossing the posterior part of inferior vena cava, then enters the hilus of the right kidney.

3.2.1.4. *Other Branches*

The other branch of the abdominal aorta, like the mesenteric inferior artery, emerges from the veno-side of the abdominal aorta at the 3rd lumbar vertebra. The calibre is small, runs obliquely and is not easily illustrated by ultrasonography. The suprarenal middle artery and the spermatic internal artery are small too, and are not easily revealed or distinguished by ultrasound.

3.2.2. Inferior Vena Cava and Its Main Branches

The inferior vena cava is on the right side of the abdominal aorta, about 2–3 cm to the right from the middle line of the abdomen. It is the trunk of the biggest vein in the abdomen. It is conglomerated from the left and right common iliac veins at the level of the 4th and 5th lumbar vertebrae. It ascends upwards along the right side of the abdominal aorta and along

the anterior part of the vertebral column. Passing through the fossa venae cavae at the posterior of the liver and the caval venous foramen at the diaphragm, it enters the right atrium and has the following main branches:

3.2.2.1. *Hepatic Vein*

It originates from the central vein at the small lobe of the liver and gradually joins the segmental and interlobular veins. It finally joins the left hepatic vein, hepatic middle vein and right hepatic vein in the shape of a fan. In most cases, the right hepatic vein unites with the inferior vena cava individually and the left hepatic and middle hepatic vein combine as a short trunk before uniting with the inferior vena cava at about 1 cm below the diaphragm, where the 2nd hilus of the liver is. The right hepatic vein is the biggest. It runs in the fissure of the right lobe of the liver while the hepatic middle vein runs in the middle hepatic fissure. The latter distinguishes the left and right halves of the liver. The proximal end of the left hepatic vein is at the fissure of the left lobe of the liver and its distal end and part of its peripheral run in the segmental fissure between latero-upper and latero-lower segments of the left liver. The venous blood supplied by the three unpaired arteries of the abdominal aorta enters the liver through the portal vein system and then enters the inferior vena cava by the three hepatic veins.

3.2.2.2. *Renal Vein*

It is the paired visceral branch of the vein of the inferior vena cava. The left suprarenal vein and left spermatic internal vein are combined and joined to the left renal vein. The left renal vein is longer, running between the abdominal aorta and the mesenteric superior artery. The right renal vein is shorter and runs horizontally. Both the left and right renal veins join the inferior vena cava at its lateral side at the level of the 1st lumbar. The left renal vein is joined to the inferior vena cava at a position somewhat higher than that of the right renal vein. The right renal vein lies anterior to the right renal artery while the left renal vein mostly lies posterior to the right renal artery.

3.2.2.3. *Portal Vein and Its Branches*

The portal vein system plays an important role in ultrasonography of the abdomen. It is usually used as a guideline for the ultrasonography of the pancreas, localization of the hepatic ducts and judgement of the portal hypertension. The portal vein is the confluence of the pancreatic vein and mesenteric superior vein. They join the dorsal side of the pancreas neck, forming the portal vein trunk. This trunk is at the posterior of the upper part of the duodenum, running obliquely towards the upper right direction to the middle of the duodenal ligament and crossing the inferior vena cava at its posterior part. In between them is the foramen of omentum, which is posterior to the common bile duct and hepatic artery. It divides into the left and right branch upon entering the liver at the 1st hilus of liver. The right branch of the portal vein is comparatively bigger and shorter, running horizontally to the right in the right liver, and it further divides into the anterior lobular vein and the posterior lobular vein. In a few cases, the posterior lobular vein further divides into upper

segmental and lower segmental veins of the posterior lobe. The left branch of the portal vein is longer. It is divided into transverse, angular, and sagital parts. The transverse part forms an angle of 120° with the right branch of the portal vein, passing through the caudal lobe and the quadrate lobe of the liver, up to the sagital portion (which lies in the fissure of the left hepatic lobe).

From sagital portion, the left branch of the portal vein further divides into the left internal lobular branch, and the left exterior lower segmental branch. At the corner, the sagital portion and transverse portion meet it, then further divides into the left exterior upper segmental branch, resulting in an "I" shape formed by the left trunk and its branch of the portal vein inside the liver. The splenic vein lies at the lower part of the pancreatic artery. Starting from the splenic hilus, it runs towards the right, along the dorsal side of the tail and the body of pancreas. At the posterior of the neck of the pancreas, it joins with the mesenteric superior vein to form the portal vein. The mesenteric superior vein lies at the right anterior of the abdominal aorta. It begins at the junction of the cecum and colon, at the root of the mesentery of the small intestine, and ascends along at right side of mesenteric superior artery along the posterior abdominal wall.

3.3. SUPERFICIAL DIVISION OF THE ABDOMEN AND THE PROJECTILE POSITION OF THE VISCERA

3.3.1. Division of the Abdomen

Position of the Viscera

3.3.1.1. *The Nine Divisions*

From the left and right middle points of the clavicles, draw a verticle line to the middle points of both sides of the inguinal ligaments respectively. Link the lowest point of both the coastal margin and anterior superior iliac spine to make two transverse lines. By these two vertical and two transverse lines, the upper abdomen can be divided into 9 regions: The left and right hypochondriac region, left and right lumbar region, left and right iliac region, and the lower abdomen.

3.3.1.2. *The Four Divisions*

Draw a vertical line from the xyphoid to the symphysis of the pubes. Draw a transverse line passing through the umbilicus. Four divisions of the abdomen are formed: Namely, the right upper and right lower abdomen, left upper and lower abdomen.

3.3.1.3. *Other Ways of Divisions*

Divide the abdomen into 6 regions: The right upper and lower abdomen, middle upper and lower abdomen, and the left upper and lower abdomen. Alternatively, the abdomen may be divided into 7 regions: The right upper and lower abdomen, middle upper and lower abdomen, left upper and lower abdomen and the umbilical region.

3.3.2. Projectile Physical Topography of the Abdominal Viscera

Right hypochondrium: Gall bladder, right kidney, right liver lobe, hepatic flexure of transverse colon, right adrenal gland.
Right lumbar region: Ascending colon, small intestine, right kidney.
Right iliac region: Caecum, appendix.
Upper abdomen: Left liver lobe, stomach, duodenum, transverse colon, portal vein, inferior vena cava, abdominal aorta, head and body of pancreas, greater omentum.
Umbilical region: Transverse colon, small intestine, ureter, abdominal aorta, inferior vena cava, mesentery, greater omentum.
Lower abdomen: Small intestine, urinary bladder, appendix, uterus and annex, postrate.
Left hypochondrium: Spleen, stomach, left kidney, splenic flexture of transverse colon, tail of pancreas, left adrenal gland.
Left lumbar region: Descending colon, jejunum, left kidney.
Left iliac region: Rectum, sigmoid colon.

Part 2

The Ultrasonographic Diagnosis of Abdominal Diseases

Chapter 4

The Ultrasonographic Diagnosis of Diseases of the Liver

Lin Liwu

The liver is the biggest parenchymal viscera and also the biggest digestive gland of the body. Before birth or during the neonatal period, it occupies nearly one half of the abdomen. Its construction and functions are very complicated and the pathological variation is great. Because of its special anatomical position, general physical examination of the liver is difficult. Also the liver is a homogeneous parenchymal viscera, so even by X-ray and isotopic examination, it is difficult to understand its internal structure. Although intra-hepatic cholangiography (e.g. hepatic angiography, cholangiography) can provide valuable information, there are inherent difficulties which cause the technique to be unpopular. X-ray and electronic computer tomography (CT) have made a breakthrough in examining the internal structure of the liver. Unfortunately, massive equipments and hazardous effect by radiation limit these techniques. Ultrasonographic technique can to a great extent analyze the structure of the soft tissue of the liver and of the parenchymal viscera. It can accurately display the construction of the intra-hepatic tissue by using acoustic characteristics. It has a significant diagnostic value for space-occupying diseases and diffusive pathological changes. More importantly, it is easy to use and safe to the environment. Due to the development of real time ultrasonography instruments, and the application of interventional ultrasonics for the diagnosis and the treatment of liver diseases, the use of ultrasonographic technique for the diagnosis of liver diseases is now entering a new stage.

4.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE LIVER

4.1.1. Morphology and Structure

From top to bottom, the diameter of the liver is approximately 15–17 cm, the transverse diameter is about 20–21 cm, and the antero-posterior diameter is approximately 10–12 cm.

It is cuneform in shape with a prominent and smooth upper surface, and an uneven and embossed lower surface. The falciform ligament divides the upper part of liver into the left and right lobes. The former is small and flat, somewhat triangular in shape, and variable in development. According to literature, the left lobe may be as big as the umbilicus or the right lobe. The right lobe is large and roughly semi-spherical. It is comparatively stable, constant, and fundamentally with the right hypochondrium. On the undersurface of the liver is a 'H'-shaped groove. This transverse groove is the hilur (the first hilus) which is formed by the bile duct, hepatic artery, and the portal vein. The left longitudinal groove is the landmark of the division between left and right lobe. Its anterior is the falciform ligament and the round ligament which embrace the free lower border. Posterior to it is the venous ligament. Anterior to the right vertical groove is the fossa where the gallbadder is found. The posterior part of the right vertical groove is the fossa for the vena cava, where the inferior vena cava lies (the second hilus).

The liver varies (long, short, and medium) in shape, depending on the person's built. The liver of a short, fat person is usually wider, the left lobe is usually beyond the left midclavicular line, presenting a transversed type position. A lean and tall person's liver is usually wide at the top and bottom, the left lobe is usually not beyond the left midclavicular line, giving it a perpendicular shape.

4.1.2. The Position of the Liver and its Nearby Viscera

Most of the right lobe is in the right hypochondrium. The left lobe of the liver is mainly in the upper abdomen, and there is only a small part in left hypochondrium. The upper border of liver is usually at the right mid axillary line crossing the 7th rib, in the right midclavicular line crossing the 5th rib, and in the median line crossing the junction of sternum and xyphoid process. The left side is located at the inner side of mid clavicular line at the 5th intercostal space. The lower border of the liver in the right axillary line crosses the 11th rib along the lower border of right costal arch, departing from the costal arch at the 7th and 8th costochondral conjugation, obliquely facing left superiorly, in the anterior median line reach about 3 cm below the xyphoid process, in the left costal arch crossing the 7th and 8th costochondral conjugation, and inclined left superiorly reaching the 5th intercostal space. The lower border of the liver of a normal adult, in general, is not over the right costal arch, but the upper border of a lean and tall built or emphysema patient is rather low. The lower border of the liver of children is also somewhat lower. In addition, the position of the liver will change with respiration, and changes in the position and movement of the viscera. We should bear this in mind during ultrasound examination.

The liver is in close proximity to many surrounding viscera. It is flanked above by the diaphragm and the lung, and heart above diaphragm. On the liver are many impressions: on the left lobe from posterior superior to anterior inferior are the impressions of the esophagus, stomach and pylorus, respectively. On the anterior, inferior right lobe are the hepatic flexture of the colon, the right segment of the transverse colon, and the impression of the duodenum. Its posterior inferior, closely in contact with the right kidney and suprarenal gland, also has an umbilicate impression.

4.1.3. The Biliary Track and its Division

The biliary tract is complicated and can be classified under the Glisson system, the hepatic venous system, and the lymphatic system. The Gilsson system comprises of the portal vein, the hepatic artery and the hepatic duct. Their distribution within liver is practically identical, whereby the portal vein is the thickest and its position is always constant. It is the main basis of division of segments and lobes inside the liver. The hepatic vein originated from the central vein within the small lobe of liver. After convergence, they assemble at the second hilus at the top of diaphragm, dividing into the left hepatic, mid hepatic, and right hepatic venous truck, and converge with some small veins before joining to the inferior vena cava. The hepatic artery and bile duct are in front of the portal vein and the calibres are small. The common hepatic duct continues to connect with cystic duct to form the common bile duct. There are some cleavages inside the liver, diving the liver into lobes and segments. The travelling direction of these cleavages with the biliary tract within the liver and ligaments are practically identical. Therefore, the liver can be divided into divisions and segments in the direction of biliary tract and ligament. From Fig. 4.1 and Fig. 4.2, we can see that the liver is divided into two lobes by the hepatic fissure and biliary tract (left and right lobes of the

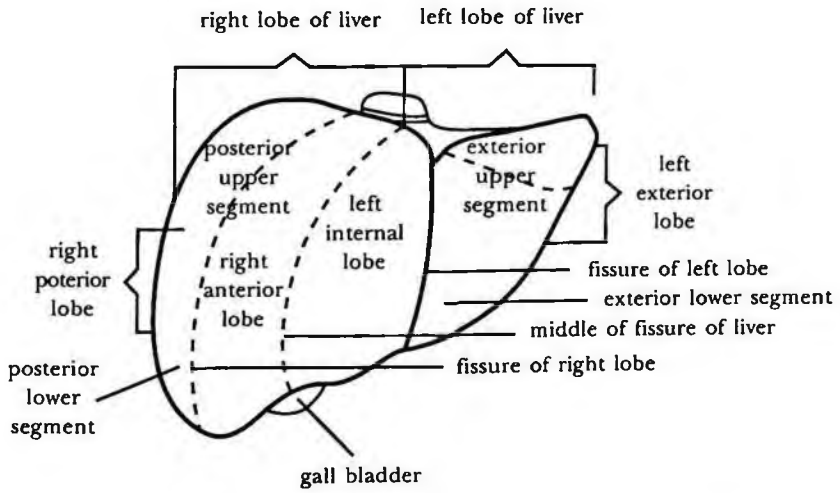

Fig. 4.1 Superior view of the lobes and segments of the liver.

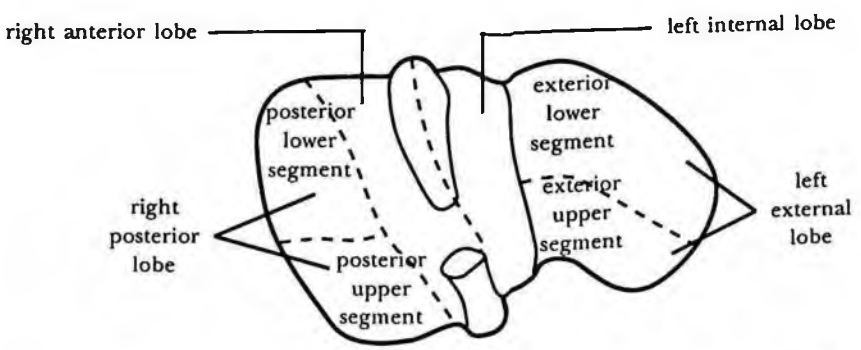

Fig. 4.2 Visceral view of the lobes and segments of the liver.

liver), four divisions (left internal division, lateral division, anterior division of the right lobe, posterior division of the right lobe), and six segments (in the left lobe of the liver: lateral upper segment, lateral lower segment, left segment of the caudal lobe; in the right lobe of the liver: posterior upper segment, posterior lower segment, right segment of the caudal lobe). See Fig. 4.1 and Fig. 4.2.

Recently, the liver has been divided into eight segments (also called subsegments, or S_1 through S_8.). The caudal lobe is segment I (S_1), the left lateral superior area is segment II (S_2), the left lateral inferior area is segment III (S_3), the left medial segment area is

Table 4.1. Anatomical Structure of the Liver and the Relationship Between the Division of the Lobes and Segments

Anatomical Structure	Position	The Function of the Divided Lobe and Segment
left hepatic vein	fissure of the left lobe of the liver	separate the cephlic ends of the internal and external lobes of the liver
mid hepatic vein	mid hepatic tissue and the liver	separate the left and right lobes of the liver
right hepatic vein	fissure of the right lobe of the liver	separate the anterior and posterior lobe of the right lobe of the liver running between the anterior and posterior branches of the right portal vein
right anterior branch of the portal vein	anterior fissure of the right lobe of the liver	symbol of the right anterior lobe of the liver
right posterior branch of the portal vein	posterior fissure of the right lobe	symbol of the right posterior lobe of the liver
transverse segment of the left branch of the portal vein	anterior lower to the caudal lobe, upper to the quandrate lobe	separate the internal lobe of the left liver (quadratic lobe) and the caudal lobe
segital segmental of the left branch of the portal vein	anterior to fissure of the left lobe	separate the middle of the left internal and external lobes
left exterior upper segment branch of the portal vein	upper segment of the left exterior lobe	symbol of the upper segment of the left exterior lobe

(Cont'd)

Table 4.1. (Cont'd)

Anatomical Structure	Position	The Function of the Divided Lobe and Segment
left exterior inferior segment branch of the portal vein	lower segment of the left exterior lobe	symbol of the lower segment of the left exterior lobe
inferior vena cava	middle fissure of the liver	separate the left and right lobes of the liver
gall bladder	middle fissure of the liver	separate the left and right lobes of the liver
venous ligament	left side fissure of the left lobe (left margin of the caudal lobe)	separate the caudal lobe and left exterior lobe
round ligament of the liver	fissure of the left lobe	separate the pedal end of the internal and external lobes
falciform ligament	cephalic end of the fissure of left lobe	separate the cephalic end of the internal and external lobes of the liver

Table 4.2. Structure of the Biliary Tract and Ligament in the Fissure of the Liver.

Fissure of the Liver	Structure of the Biliary Tract and Ligament	
middle fissure of the liver	cephalic end:	middle part of the caudal lobe, where the middle hepatic vein converges into the inferior vena cava
	middle portion:	middle segment of the middle hepatic vein, trunk of the portal vein, transverse segment of the left branch, where the common bile duct and common hepatic duct divide
	pedal end:	starting segment of the middle hepatic vein, gall bladder fossa
fissure of the right lobe	cephalic end:	where the right hepatic vein converges into the IVC (about 1/4 of the whole length)
	middle portion:	long branch of the right hepatic vein
	pedal end:	long branch of the right hepatic vein

(Cont'd)

Table 4.2. (Cont'd)

Fissure of the Liver	Structure of the Biliary Tract and Ligament	
fissure of the right segment of the liver	cephalic end:	vein of the right posterior lobe
	middle portion:	where the right superior segment vein and the inferoposterior segment vein divides
fissure of the left lobe	cephalic end:	where the left hepatic vein converges into the IVC (about 1/4 of the whole length), inclined to the left fissure of the venous ligament
	middle portion:	sagital segment of the left portal vein
	pedal end:	round ligament of the liver
fissure of the left segment	middle portion:	left hepatic vein (mid 1/3)
	lateral side:	left hepatic vein (exterior 1/3)

segment IV (S_4), the right anteroinferior area is segment V (S_5), the right posteroinferior area is segment VI (S_6) and the right posterosuperior area is segment VII (S_7). The right anterosuperior area, which is not seen from the caudal side of the liver, is segment VIII (S_8).

4.2. ULTRASONOGRAPHIC EXAMINATION OF THE LIVER AND THE METHOD OF DIAGNOSIS

4.2.1. Re-adjustment of the Instrument

The high resolving power gray scale real-time ultrasonographic diagnostic apparatus is widely used nowadays. Examination for adult linear array real-time imaging apparatus is used. For children and lean people, sector scanning or arc scanning are used. The static scanning ultrasonographic apparatus is seldom used. It is suitable for serial tomographic scanning of the liver, particularly for large focus, and the observation of structural relations of nearby tissues. The image is clear and easily analyzed. According to the type of apparatus and the various frequency of the probe, undergoing proper readjustment, such as for the linear array scanning apparatus (frequency –3.0–3.5 MHz), the general overall gain take is 30–35 dB. Near region suppression is –20––25 dB, far region elevation is 3.0–3.5 dB/cm. For the arc scanning apparatus (frequency = 3.0–3.5 MHz), under common conditions, the overall gain is 40 dB, the near region suppression is –25––30 dB and the far region elevation is 3.0–4.0 dB/cm. But for a fat person or a patient with a fatty liver, the elevation for the far region may elevate to 4.0–4.5 dB/cm due to obvious attenuation. In this way, we minimize misdiagnosis of deep seat focus due to artifact by-covering.

The regulation of focusing can be determined by the location of the focus. Shallow focus is usually used for the near region one section focusing (N), other locations depend on the depth by selecting middle region (M) or far region (F1, F2) focusing. For other regulations

see previous description. After regulation, the normal liver parenchymal echo, no matter shallow or deep, will probably become even, revealing only the middle- or low-intensity, diffusive dot-like echoes, consequently, causing the echo of the hepatic vein, inferior vena cava and gall bladder to form a non-echoing dark area.

4.2.2. Preparation of Patients

No special preparation is necessary for the examination of the liver. But sometimes for exclusion of biliary tract diseases especially diseases of the gall bladder, the patient should avoid oily food for a day.

4.2.3. Method of Examination

The patient is usually in the supine position first. In some cases, the position of the liver is too high, causing difficulty during examination. The patient may take the sitting position with both feet lowered, or he may take deep respiratory movement to let the liver descend in order to facilitate the examination. For the sake of widening the area of observation, during examination a proper change of the position is necessary. For the biliary system, lying on left side with a 45°–90° angle is desirable, so that the liver will shift down in order for the structure of hilus of liver below the rib to be observed. The prone position is convenient for the examination of the right posterior lobe of the liver from the back. The usual position and order of examination are shown in Fig. 4.3.

The figure on the left represents the sketch map of six sectional positions and the right figure shows the relationship between the blood vessels in the liver with the sectional surface.)

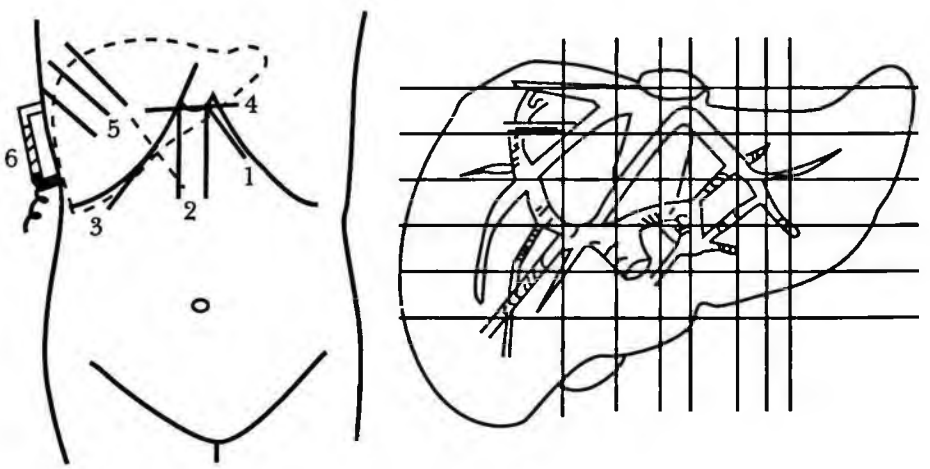

Fig. 4.3 Sketch map of the sectional position of the liver. (1) Slanting subcostal section of left; (2) Subxypholid section; (3) Right subcostal section; (4) Transverse section of the liver; (5) Slanting section of the right intercostal space; (6) Coronary section of the right liver.

4.2.3.1. *Vertical Sectional Scanning of Liver*

Usually, beginning from the left side of the liver, position the probe on the left side of the xyphoid of the upper abdomen, and let the level of the sound beam be parallel to the mid abdominal line. Moving slowly from left to right, combined with a fan-shaped side moving probe, examine the vertical cross-section of the left liver, then repeat once from right to left. During examination, make sure the diaphragm surface of the left liver is in full view as far as possible. Let the sound beam of the probe slant a little along the sagital surface, moving towards the head of patient, and either shift the probe upwards or ask the patient to breathe deeply until the image of the diaphragmatic surface of the liver and the palpitation of the heart are revealed.

After clearly revealing the liver, move the probe parallel towards the right liver and ask the patient to breathe deeply at the same time. Let the liver move down in order to increase the revealing area.

For patients whose liver occupy a higher position, the vertical section of the right liver is usually limited, and is greatly influenced by the rib. This time, the patient is made to lie on the left side, or other sections such as the intercostal slanting section along the costal margin in order to make up the defect (Fig. 4.4).

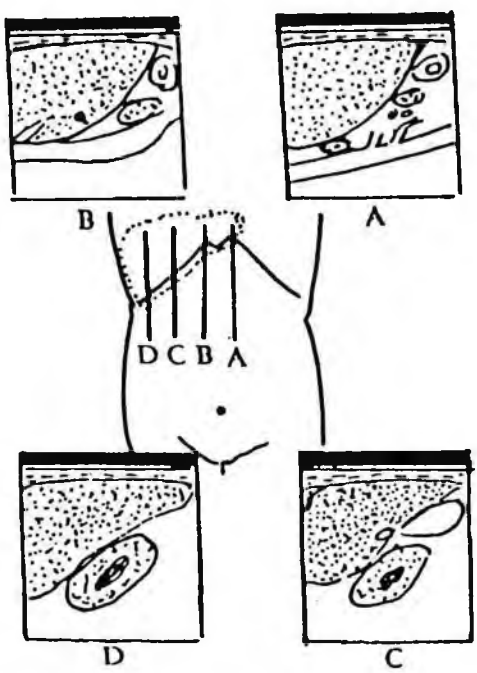

Fig. 4.4 Sketch map and typical section of the longitudinal section of the liver. (A) Anterior longitudinal section of the abdominal aorta; (B) Anterior longitudinal section of the inferior vena cava; (C) Longitudinal section of the liver and gall bladder; (D) Longitudinal section of the liver and right kidney.

4.2.3.2. *Oblique Section Below the Coastal Margin*

(1) Oblique section below the left costal margin.
To make clear the diaphragmatic surface of the left side of the liver and the portion covered by the costal arch and the xyphoid, place the probe below the left costal margin. Let the surface of the sound beam face the left shoulder of the patient, and gradually move it to the middle line. Under this section, we can also observe the left side of the liver. Sometimes the fundus and the cardia of stomach can also be seen.

(2) Below the right costal margin and along the right costal arch section.
These are to be considered as the most important method of ultrasonic scanning of the liver. Place the probe on the margin of the right rib and parallel to the costal arch. Let the sound beam move to the right diaphragm of the patient from a perpendicular position, slowly moving along the costal arch. The total surface of the sound beam will scan the right side of the liver. The outline of the right liver can then be seen. The hepatic parenchymal echo, the image of the intra hepatic blood vessel, and the diaphgram and its movement with respiration can be disclosed. If there is any fluid accumulated in the thoracic cavity and other comparatively large space, pathological changes near the surface of the diaphragm can also be examined. But the examination for obesity and flatulence in the abdominal cavity is rather difficult. Let the patient lie on the left side so the liver is displaced downward and approaches the margin of right rib. This position is easier for examination. Usually the sound beam of probe points perpendicularly to the dorsal side of the patient first, and then gradually slants to the scapular region, and finally it points to the caudal side. The angle of scanning is usually 60°–90°.

The image of the section below the right costal margin is similar to the cross section of the liver; it is usually applied for the examination of the structure of the hilus of the liver like the portal vein, biliary tract and its branch. It is also used for the examination of the gall bladder.

4.2.3.3. *Examination Along the Intercostal Space*

Place the probe on the right intercostal space (about 7th–9th intercostal space). It may reveal the upper border of the liver, the anterior surface and hilus of the liver, thus making supplementary observation for any pathological changes inside the liver and the echo of the blood vessel. It is also the main method commonly used for percutaneous hepaticpuncture for biliary drainage guided by ultrasound.

4.2.3.4. *Cross-Section of the Liver From the Top of the Liver Downwards*

By making parallel sections of 1–2 cm intervals, a series of cross-sections of the image of the liver can be obtained. But using this section, the diaphragmatic surface of the liver and demarcation of "liver-lung" cannot be revealed (Fig. 4.5).

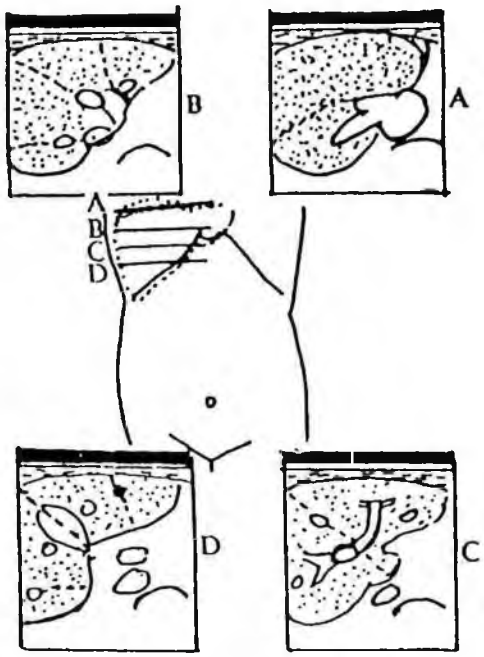

Fig. 4.5 Sketch map and typical cross section of the liver. (A) Transverse section of the right hepatic vein; (B) Transverse section of three hepatic veins; (C) Transverse section of the transverse groove of the hilus of the liver; (D) Transverse section of the gall bladder.

4.2.3.5. *Coronary Section of the Liver*

Place the probe on the right posterior axilliary line in order to make the coronary section examination for the liver (right liver) from the posterior axilliary line to the anterior axilliary line. It may reveal the morphology of the parenchyma at the top of the right liver and the diaphragmatic surface, subphrenic fluid-retention and hydrothorax. It is also used for the observation of the right kidney, gall bladder and the surrounding condition.

Using the above section total surface, the whole liver can be revealed. This is a net-weaving type examination. In order to raise the rate of diagnosis, the following precautions should be taken while examining the liver:

(a) Pay attention to the change of position and co-ordination with respiration. During the examination of the liver, multiple positions should be used, so that every part of the liver can be fully exposed. For instance, the supine position is adapted to reveal the diaphragmatic dome of the right lobe and the right posterior lobe. The prone position is used to examine the pathological changes of the superior and inferior segments of the right posterior lobe. Changing position is helpful for the differentiation of intrahepatic cholelith or "bile gas", and is also used as a test for shifting of the content inside the liver due to gravitational forces, such as a liver abscess. During the examination of the liver, the co-ordination of respiration is also important. By holding the breath, a more extensive structure of the liver can be observed by the subcostal obliqued section. A part of the liver tissue originally covered by lung tissue may be clearly revealed by expeling air from the lungs, and holding still.

(b) Familiarity with ultrasonic anatomy eliminates easily missed areas: the anatomical position of the liver is very complicated. Using ultrasonic examination, pay special attention to several areas, such as the diaphragmatic dome of the right lobe, the right hypochondrium, the juncture of the liver and kidney of the right lobe and the inferior angle of the right lobe from the mid axilliary line to the mid clavicular line, the left stretching portion of the left exterior lobe, the hilus of the liver, and surrounding area of gall bladder. Examination is done according to the ultrasonic anatomy. The lobe or segment is examined by segment in order.

(c) Careful observation must be made on tiny focus and areas with slight difference in the echo. During the examination of the liver, the discovery of tiny focus is very important. Examination is usually conducted from multiple directions, and different angles to see whether there is a focus. Ask the patient to hold his breath after steady breathing, then move the probe laterally. It will reveal the outline. A fixed sound beam on the surface can also be used. Ask the patient to breathe slowly and steadily. Let the liver tissue move to and fro along the sound beam surface, so that the tiny focus can be easily detected while the liver moves with respiration.

(d) Installation of the disposal image in the equipment. Select a proper post-disposal, or use false colour image. Let the echo of the tiny focus and the demarcation of echo of the surrounding tissue become more defined in order to raise the resolution of the tiny focus.

4.2.4. The Diagnostic Method of Ultrasonography of the Liver

The ultrasonographic diagnostic method of the liver is similar to that for other viscera. According to the anatomical, pathological and physiological characteristics, the analysis is done in the following ways.

4.2.4.1. *The Size and Morphology of the Liver*

The size of the human liver varies greatly. It is influenced by many factors, such as the size of the thoracic cavity, whether there is emphysema, ptosis of viscera, obesity, etc. The liver has an irregular geometrical body; it is very hard to get a standard section, and the measuring value is not easily repeated, therefore, the measuring value of the liver is for referential purposes only. Some people think that the oblique section of the second hilus of the liver is the biggest oblique diameter of the right liver, taking the perpendicular section of the mid right clavicular line as the thickness of the right liver to estimate the size of the right lobe. The contour of the liver also varies. The liver has a wedge-shaped structure; the margin of the section has a definite angle. The longitudinal section of the lower end of the left lobe is about 45°, the lower end of the longitudinal section of the right lobe is 75°. If the angle is found to be obtuse, this indicates an enlargement of the liver or the presence of a focus. The margin of the liver also varies greatly. A smooth margin is seen in a normal liver, or diffusive without distinction in fibrosis of the liver. A rough and protuded margin may be seen in big nodular cirrhosis of the liver, liver tumor, liver abscess and some other space-occupying lesion inside the liver. An uneven or nodular margin is mostly seen in cirrhosis and metastatic tumor. A sunken margin indicates pressure from outside, such as the right

subphrenic abscess, right kidney or retroperitoneal tumor, tumor of the pancreas, gastrointestinal tumor or swelling of the lymph nodes.

When observing the size and morphology of the liver, we must pay special attention to the normal variation of the caudal lobe of the liver because the caudal lobe of a normal person varies with the individual. While doing a longitudinal section in front of the inferior vena cava, we may find an oval region formed by the crowding of the left branch of the portal vein, inferior, vena cava, and venous fissure ligament. Above the cross-section, it is usually tongue-shaped. Sometimes the body of the caudal lobe is rather big and obtuse and commonly mistaken for a tumor (Fig. 4.6). Otherwise, because the location of the caudal lobe is rather deep, by the influence of the ventral side fibrotic structure, the echo from the tubular wall of the venous ligament and portal vein results in the remarkable attenuation of sound there. Ultrasonographic image usually reveals the image of a low echo tumor. By changing the direction of the examination, we can observe the form and border of the caudal lobe, and whether there is deformity or compression of the blood vessel around the caudal lobe. This will provide some useful information for diagnosis.

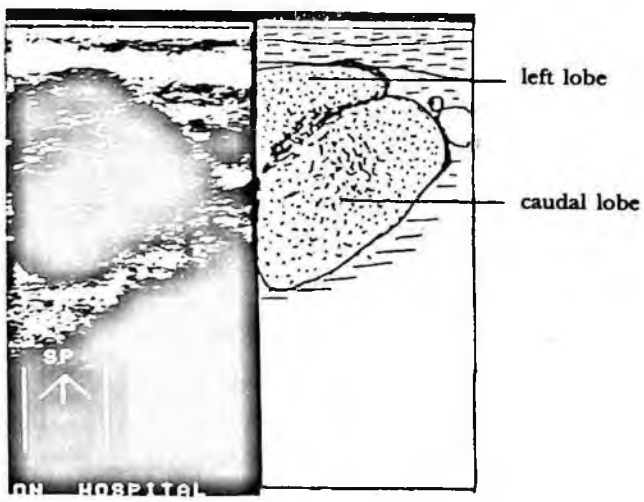

Fig. 4.6 Enlargement of the caudal lobe of the liver.

4.2.4.2. *The Intensity and Distribution of the Echo of the Parenchyma of the Liver*

The echo of a normal liver is evenly distributed and of medium strength. Various pathological changes present different strengths and distribution of the echo. Several types are seen as follows:

(a) Diffusive increase of the echo: it is presented as an increase in strength of the echo of the entire liver. It is commonly seen in non-specific inflammation of the liver, extravasation of the liver, and extensive obstruction of small biliary ducts inside the liver. In the case of a localized increase of echo, it can mean a localized cirrhosis of the liver, or bacterial infection.

(b) The echo of pathological changes of local focus: a pathological change of the local focus is usually analyzed by marginal echo. If the border of a focus is thin, cystic pathologic changes within the liver, or small attenuated type tumor, is mostly seen; increased marginal echo usually means the presence of an abscess in the liver; if the marginal echo shows a step-down decline, it indicates inflammatory pathological changes such as a liver abscess. A dark circle (sound halo) of low echo can be seen in the margin. If a strong light wheel of echo is seen on the anterior side, it is most likely to be carcinoma of the liver. If the margin presents a relief sculpture, it is most likely to be hemangioma; irregular margin or insect-encroachment are commonly seen in liver abscesses, pseudopodia extension or a satellite-like nodules seen in the margin may be carcinomatous tissue of the liver growing or spreading outwards.

(c) Even nature of the internal echo: uneven distribution of light dots inside the liver usually means mild fibrosis. Chronic liver disease usually reveals linear or strand-like echo. An uneven echo of the local focus suggests severe cirrhosis of the liver. An uneven network in the small lobe of the liver indicates schistosomiasis.

(d) The intensity of the echo within the focus: according to the characteristics of the focus, the intensity of the echo within the focus can be divided into:

(i) Strong linear echo — commonly seen in gas inside the biliary tract, namely "bile gas".

(ii) Strong echo light dots or hyperechogenic mass: mostly seen in calcification or stone formation of fibrostic nodules of the liver.

(iii) Hyperechongenic mass of strong echo area: commonly seen in primary big mass carcinoma inside the liver, nodular cirrhosis of the liver, hemangiosarcoma and a large stone, etc.

(iv) Identical echo area: this is a rather difficult to distinguish type of focus inside the liver. It is mostly seen in small carcinoma of the liver, and is easily misdiagnosed.

(v) Low echo (weak echo) area: local echo weaker than that of the normal liver tissue is commonly seen in a malignant tumor, such as carcinoma of the liver, metastasis of lymphosarcoma to the liver, hemangioma, or small abscess in the liver.

(vi) Echo-free area: minute light dot means turbid fluid commonly seen in the abscess of the liver. Echo-free area indicate the presence of clear fluid commonly seen in the cyst of the liver.

4.2.4.3. *Observation of Changes of the Biliary Tract Inside the Liver*

As mentioned earlier, all types of changes in the biliary tract can accurately reflect the pathological changes.

(a) The disease causing the biliary tract inside the liver to thicken.
Hepatic vein system: heart disease or obstruction of the inferior vena cava and hepatic vein, overload of the right heart, pericardial retention of fluid, downward displacement of the tricuspid valve syndrome, right heart failure, hepatic venous obstruction syndrome, or hepatic vein dilation due to pressure or tumor thrombus. The left hepatic vein is 5 mm in a normal human being, the mid hepatic vein is about 5–7 mm, and the right hepatic vein is about 7–10 mm. Dilatation of the hepatic vein usually causes enlargement of the liver, i.e extravasation (Fig. 4.7).

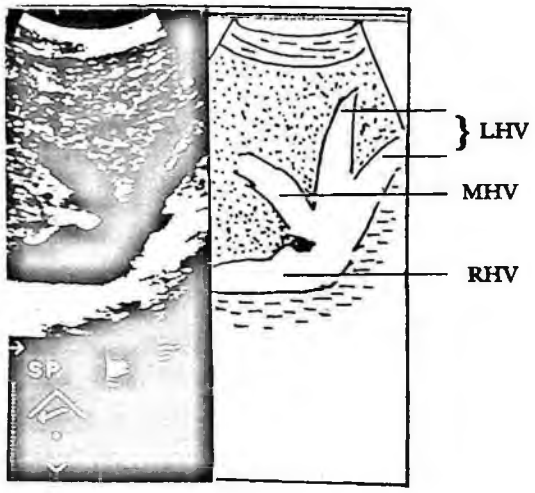

Fig. 4.7 Dilatation of the hepatic vein.

The portal vein system: cirrhosis of the liver or hypertension of the portal vein, portal vein pressed by the tumor in the hilus of the liver or thrombus within the portal vein, or tumor embolus obstructing the distal end causes dilatation of the proximal end. But the calibre of a normal portal vein varies greatly, the trunk of the portal vein may be within 8–15 mm, the calibre of the left and right branches are about 6–7 mm. Therefore, data from measurement serves as a reference only, and should be combined with other signs to make a diagnosis.

Biliary tract system: the calibre of a normal common bile duct is 4–8 mm, the left and right hepatic duct is only 1–2 mm, therefore not easily identified.

Dilatation of the biliary tract system indicates pressure on the biliarty tract, or obstruction inside the lumen. According to the position of dilatation, we may analyze the position of the pressure or obstruction. Dilatation of the whole biliary tract indicates obstruction or oppression to the lower segment of common bile duct, as in the case of a stone in the lower segment, ascaris, tumor of the ampulia, and carcinoma of the head of the pancreas. Dilatation of the intra-hepatic duct without dilatation of the lower segment of the common bile duct mostly indicates that a tumor is exerting pressure on the hilus of the liver, or obstruction of the upper segment of the common bile duct (mostly due to tumor). If no dilatation of the common bile duct occurs, and only one branch of the left or right hepatic duct is examined, this means an obstruction or oppression has occured on the biliary tract. Extensive dilatation of the small biliary tract inside the liver mostly means hepatitis of the small bile ducts, (cirrhotic cholangitis) (Fig. 4.8).

(b) Diseases causing the biliary tract inside the liver to become smaller.

The hepatic vein becomes smaller: mostly seen in fatty liver and extensive fibrosis of liver.

Diseases causing the portal vein to become smaller: mostly found when the portal vein inside the liver becomes smaller, such as in severe cirrhosis of the liver and inflammation of the portal vein.

Diseases causing the biliary tract to become smaller: mostly seen in cholangitis and congenital stenosis of the biliary tract.

(c) Displacement or disappearance of the biliary tract inside the liver. The displacement of the biliary tract inside the liver is mostly seen in space-occupying pathological changes inside the liver, or it may be due to stretching by severe fibrosis. The disappearance of the biliary tract is mostly due to fibrosis, cirrhosis or obstruction of biliary tract, or twisting of the tract companied by a decrease in thickness. In infants, obliteration of the biliary tract is due to congenital impotence of the infant's biliary tract.

(d) Abnormal echo from the intrahepatic biliary tract. Thrombus or tumor embolus can be seen inside the hepatic vein, abnormal echoes of the thrombus and tumor embolus are commonly found inside the portal vein or inflammation of the vein, or the echo from a slow blood stream by the movement of piles of RBC due to slow blood flow, as in the case of portal hypertension due to cirrhosis. Abnormal echo from the biliary tract is far more common, e.g in stones, ascaris, tumors, bile clay or gas. While observing abnormal echoes inside biliary tract, we must note the second echo-producing artifact.

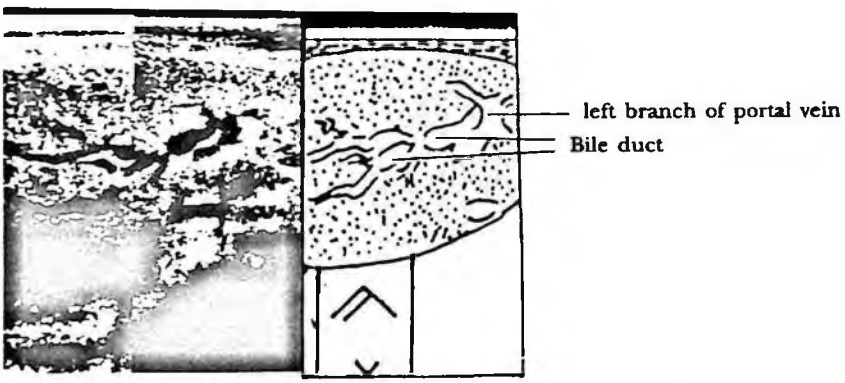

Fig. 4.8 Dilatation of the biliary tract inside the liver.

4.2.4.4. *Observation of Special Ultrasonographic Image Inside the Liver*

Sometimes, a focus inside the liver may give special characteristic variations which have great values in diagnosis. Some examples are:

(a) Bull's eye sign
The intensity of the echo increases in the centre of focus inside the liver, while there is a decreased dark circle of more than 3–5 mm in the surrounding. This is mostly seen in metastic carcinoma, such as carcinoma of the breast or lung which metastasized to the liver. Some cases are seen in primary carcinoma of the liver.

(b) Target-like sign
The centre of the focus is a dark area, while its surrounding is an area of increased echo. Its outer layer is again a low echo area, forming a bright and dark intersecting area similar to an image of a target. This is commonly seen in ultrasonographic images showing the metastasis of the alimentary tract tumor to the liver, such as in carcinoma of the stomach, and carcinoma of intestine.

(c) Sound "halo" sign

A dark circle of no echo or low echo around the focus, mostly seen around the focus of the carcinoma of the liver. Some people think it is necrosis or calcification of the nodular centre of the tumor that makes its sourrounding echo comparatively low. Some think it is the infiltration of the growth of tumor nodules, causing edema of the surrounding. Recent research points out that it is probably the growth of the tumor, thus exerting pressure on the normal tissues. On the one hand, it causes marginal resistance resulting in uneven, successive decreasing echo. On the other hand, it decreases the rise and fall of the uneven pressed layers as the result of comprehensive function, thus decreasing the reflected echo. This sign has a definite value in the ultrasonographic diagnosis of the carcinoma of the liver. In individual cases of hepatic hemangioma, there is sound halo surrounding the focus, so one must pay attention in the differentiation.

(d) Light wheel sign

At the interior border of the focal tissue within the carcinoma of the liver, there is a bright area of echo called the solar halo or the lunar halo. Recent research regards it to be a conversion with certain degree of roughness on the surface of the focus and at the acoustic impedance between the focus and normal tissues. The surface of the primary carcinoma of the liver is usually rough and uneven, and has different acoustic impedance with normal liver tissue. Therefore, the light wheel is usually found in front of the carcinoma. The surface of hemangioma is usually smooth and the acoustic impedance is small, therefore this phenomenon is seldom seen.

Certainly, the appearance of a light wheel has a connection with the angle of examination, the size of tumor and the back reflection (Fig. 4.9).

(e) Daughter cyst's, mother cyst's image

It is seen in an ultrasonographic image of echinocousis that within a big cyst there is a daughter cyst, or within a daughter cyst is another daughter cyst.

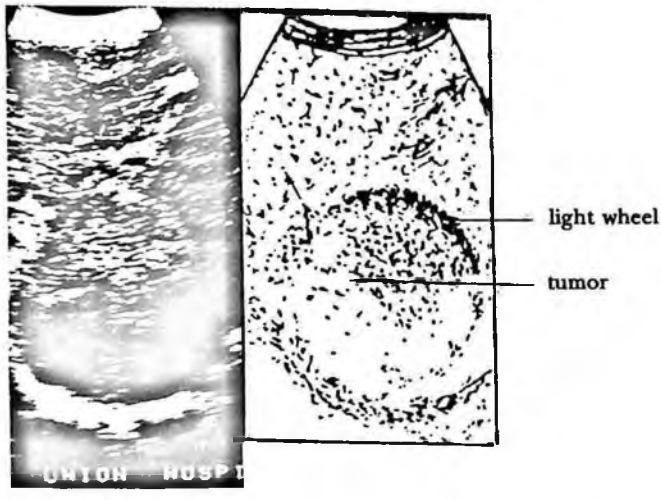

Fig. 4.9 The light wheel phenomenon of the carcinoma of the liver.

4.3. SONOGRAM OF A NORMAL LIVER

The membrane of the normal liver is usually uniform and smooth, and presents a strong linear echo that gives the outline of liver. The diaphragmatic surface is curved and has a rather strong echo. The visceral surface of the liver is usually concave inside or flat, with a sharpened margin. The echo signal of reflection from the parenchyma of the liver is weak and dark grey in color. Furthermore, its interior consists of light, small and even dots. The biliary tract near the hilus of the liver is gradually increased. The channel with a thick wall and strong reflection is the portal vein. In all sections, the hepatic vein presents the thinner wall, with a lower echo and small calibres, extending to the second hilus. In the hilus region, the extrahepatic duct of the ventral side of the portal vein can be seen, for example the superior segment of the common hepatic duct and common bile duct, where the left and right branch of common hepatic duct can be distinguished.

4.3.1. Sonography of the Liver at Different Sections

4.3.1.1. *Transverse Section of the Liver*

Due to the interferences by the rib and the gas inside the gastrointestinal tract, applying ultrasonography for the cross-section examination of the liver is very difficult, particularly when using a linear shower probe. Therefore, it is seldom used clinically. However, cross-section is very useful for anatomical localization of intrahepatic focus and for intrahepatic construction. It is still an indispensable section for the examination of the liver. Several typical cross-sections of the liver are as follows:

(a) Cross-sections through the gall bladder
Examination can be conducted either above or below the intersection of the right midclavicular line and the right hypochondriac border. This section is somewhat higher than that of the umbilicus. It passes through the round ligament of the liver such that the free end or body of the gall bladder can be revealed. It can also reveal the right kidney located at posterior to the echo, the gall bladder, and the parenchyma of the liver. A normal liver is divided into the left and right half by an imaginary line from the gall bladder to the inferior vena cava (Fig. 4.10).

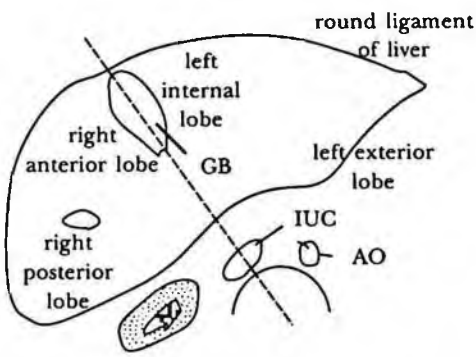

Fig. 4.10 The sketch map passing through the cross-section of the gall bladder.

(b) Cross-section through the transverse groove of the hilus of the liver

When the probe is moved down from the top, and passes through the hilus of the liver, the tract becomes clear. The portal vein is actually divided into left and right branches at the hilus of the liver, forming an angle of 150°. The ultrasonographic image may show the entire length of the right branch, the vein of the right anterior lobe and right posterior lobe. The transverse segment of the left branch of the portal vein usually extends toward the left at an angle of 30°. At the angular region, turn 90°–120° to the front and form a sagital ligament. The transverse segment on the left branch of the portal vein is anterior to the inferior vena cava. This section can also disclose the mid-hepatic vein to locate the anterior from the right branch of the portal vein. It passes through the imaginary line from the left margin of the inferior vena cava to the mid hepatic vein, extend to the right anterior, where the mid hepatic fissure is located. Thus, the transverse segment becomes the landmark to divide the liver into the left and right lobe. It divides the right anterior lobe and left internal lobe in front of the hilus of the liver. Posterior to the hilus, it divides the caudal lobe into left and right segments (Fig. 4.11).

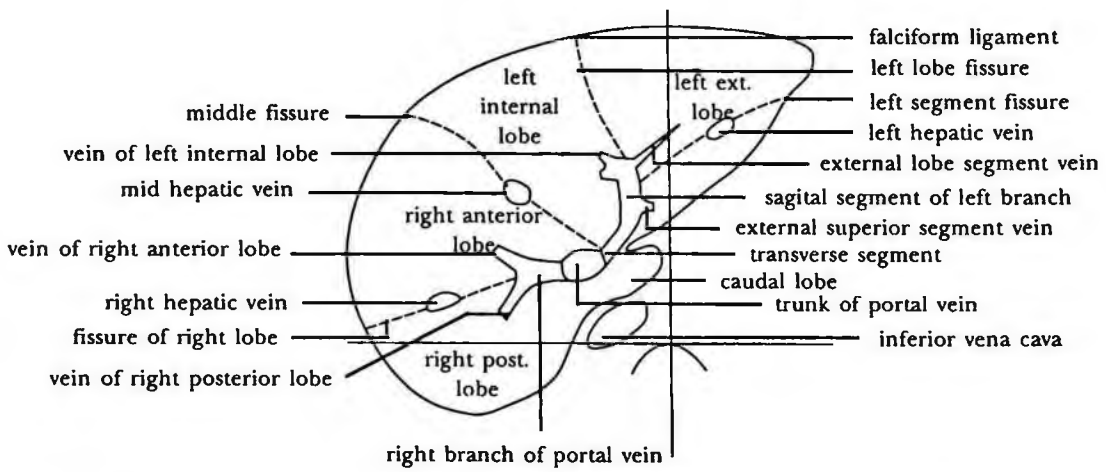

Fig. 4.11 Sketch map of the cross-section through the transverse groove of the hilus of the liver.

(c) Through the cross-section of the second hilus of the liver

The oblique cross-section of the beam surface passes through the hepatic vein to converge into the inferior vena cava (after revealing the hilus of the liver, let the probe slant about 45°–60° towards cephalic end). The left, middle, and right branches of the hepatic vein may present radiative distribution, and converge into the inferior vena cava. The wall of the hepatic vein is thin and smooth, and the demarcation between the non-echo of the tubular structure and the echo of the parenchyma of the liver is very distinctive. In a practical examination, we find only two branches of veins. Among the mid hepatic, the right hepatic and the left hepatic veins converge into the inferior vena cava at the same time. The small area is surrounded by the inferior vena cava, the mid-hepatic vein, the left hepatic vein, and the dorsal fissure in the upper part of the caudal lobe (Fig. 4.12).

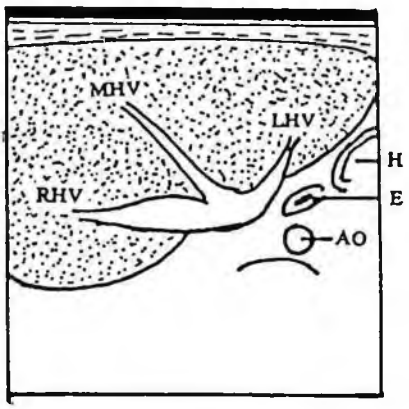

Fig. 4.12 Sketch map of the cross-section through the second hilus of the liver.

4.3.1.2. *Longitudinal Section of Liver*

Place the plane of the probe in the direction of the long axis of the body, from left to right, and do a series of longitudinal sections of the liver:

(a) Longitudinal section through the abdominal aorta
Place the probe below the xyphoid on the upper abdomen, a part of it may be the xyphoid. It exposes the sagital section of the lateral lobe of the left liver. The diaphragmatic surface of the liver is somewhat flat or curve, the undersurface is sharp forming a 45° angle. The organs posterior to the liver can also be disclosed, like the slower segment of the esophagus, the stomach, the body of the pancreas, the hepatogastric ligament, the abdominal aorta and its branch (Fig. 4.13).

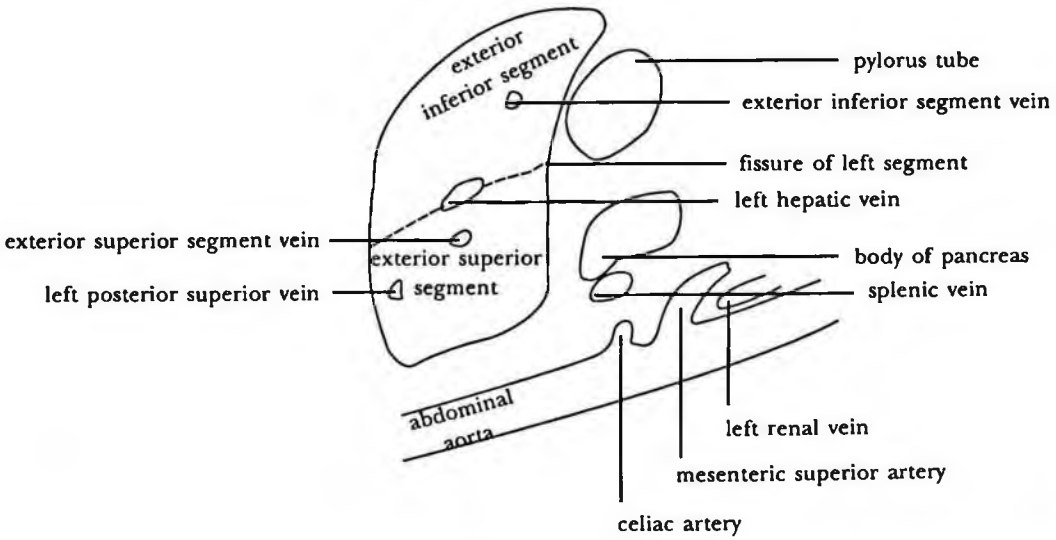

Fig. 4.13 Sketch map of the longitudinal section of the liver through the abdominal aorta.

(b) Longitudinal section through the inferior vena cava
Approximately 3–4 cm from the right to the middle line, the internal lobe of the left liver (that is the quadrate lobe) and the sagital section of the caudal lobe can be revealed. The diaphragmatic surface of the liver is somewhat curved and located directly below the heart. The lower margin is clear, however, it is near the stomach, head and neck of the pancreas. The caudal lobe at its posterior is near the inferior vena cava, right at the entrance of the inferior vena cava into the right atrium. One may find the opening of mid hepatic vein. The run of the inferior vena cava is concave, the wall is thin, and the lumen varies greatly from the lumen of the abdominal aorta. In front of the inferior vena cava, the trunk of portal vein can be observed (Fig. 4.14).

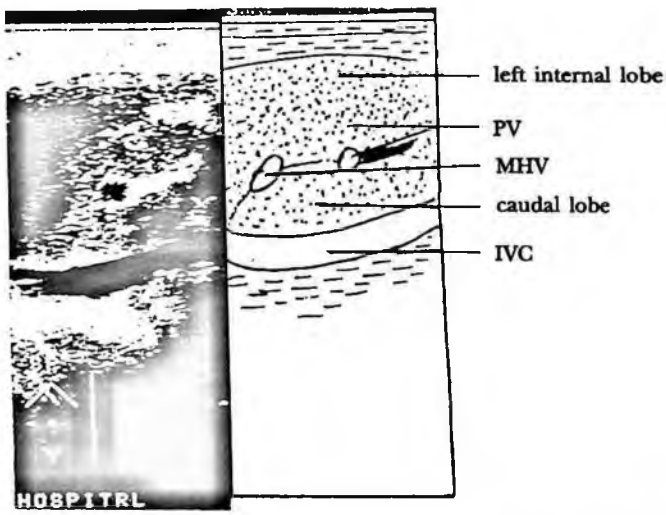

Fig. 4.14 Ultrasonographic image of the longitudinal section of the liver through the inferior vena cava.

(c) Longitudinal section through the liver-gall bladder
This section is often used to reveal the relationship between the liver and gall bladder. It is also the longitudinal section of the hilus of the liver. Here the structures of hilus can be disclosed (i.e the gall bladder, the common bile duct, and the portal vein). The liver is circularly curve at the dome of the diaphragm (it may also reveal the mid-hepatic vein, the neck of the gall bladder pointing to the hilus, the bottom of the gall bladder at the right side of the image). This section also serves as the landmark of the left and right lobes (Fig. 4.15).

(d) Longitudinal section through the liver and the right kidney
Placing the probe between the right side of the mid-axilliary line and the mid clavicular line in order to conduct the scanning examination using the longitudinal section may reveal the right lobe of the liver and the relationship between its posterior surface with the right kidney. The left side of the sonographic image is the diaphragmatic dome portion of the right lobe, whereas the right side of image is the lower angle of the right liver and kidney (Fig. 1.16).

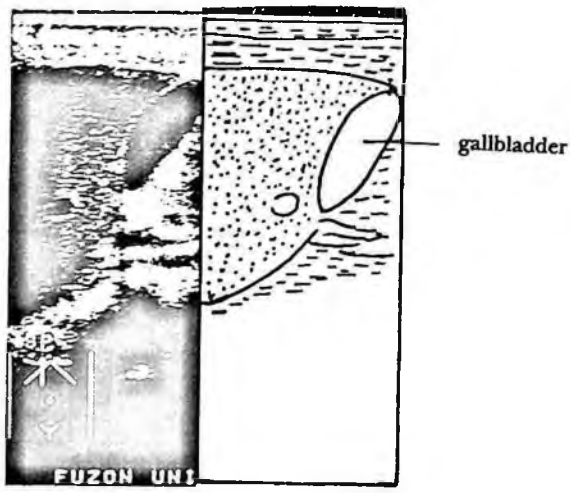

Fig. 4.15 Ultrasonographic image of the cross-section of the liver through the gall bladder.

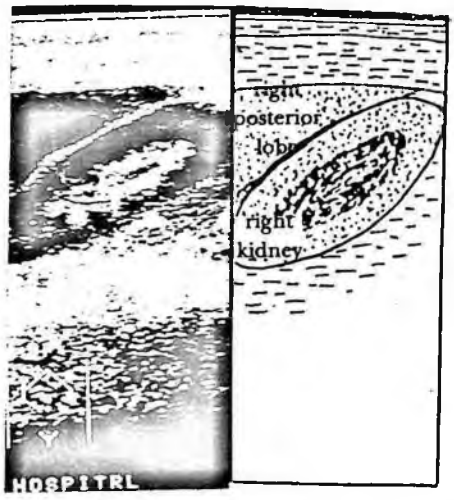

Fig. 4.16 Ultrasonographic image of the longitudinal section through the liver–kidney.

4.3.1.3. *Oblique Section of the Liver Below the Right Costal Margin*

Place the probe below the right costal margin, and make an oblique section of the liver approximately parallel to costal margin. Due the difference between the probing angles, the liver can be divided into many sections as follows:

(a) Section of the branch of the portal vein
It is the section passing through the transverse groove of the hilus of the liver. It may reveal the branch of the portal vein. The left side of the image is at the right anterior lobe — it is the right anterior lobe of the liver. In the middle is the liver. It is the long axis of the gall bladder, left and right branches of the portal vein and inferior vena cava.

The left branch of the portal vein extends transversely to the intersection of the internal and external lobes, bending toward the abdominal wall and forming the cystic portion. Further upwards it becomes the strand-like echo zone of parenchyma which extends to the border of the liver — it is the round ligament of liver. At another end of the cystic region, a strand-like parenchymal echo zone can be seen directly connected with the inferior vena cava, namely, the fissure of venous ligament. The image in this section, the imaginary line connecting the mid-gall bladder line with the left inferior vena cava may divide the liver into the left and right halves. In the left half, the imaginary line links together the round ligament of liver, the proximal end of the sagital section, and the fissure of the venous ligament. This line may further divide the left liver into the left internal lobe (quadrate lobe) and left external lobe.

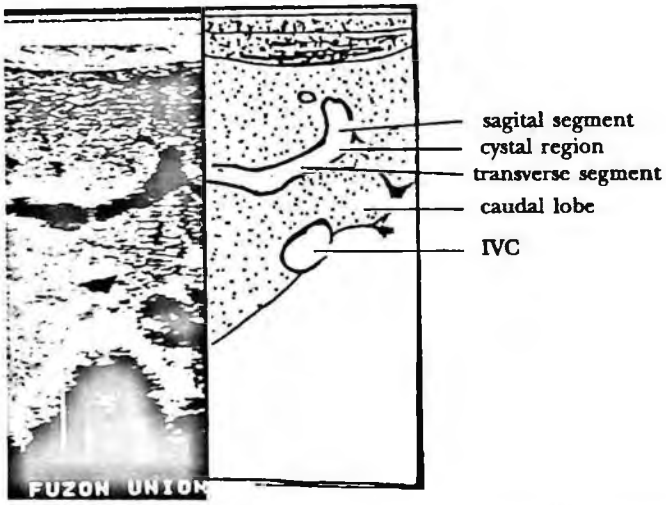

Fig. 4.17 Cross-section of the portal vein of the cystic region.

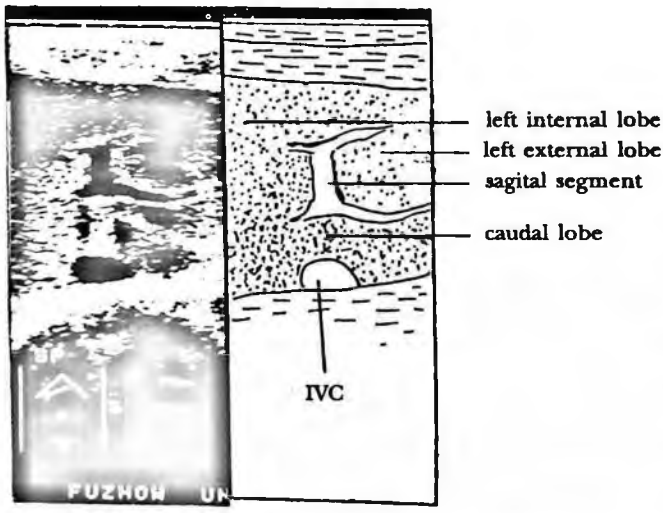

Fig. 4.18 Sagital portion of the left branch of the portal vein.

The caudal lobe lies between the left branch of portal vein and the inferior vena cava. The transverse segment of the left branch of portal vein separates the quadrate and caudal lobes. The small area of the right side of the gall bladder (left side of the image) is the visceral surface of the right anterior lobe, and the rest of the section is the right posterior lobe (Figs. 4.17–4.18).

(b) Section of the hepatic vein

This is the oblique section of the second hilus of the liver. It may reveal the whole length of the trunk at the right hepatic vein, and a large portion of mid hepatic vein; the cephalic end of the left hepatic vein, and the entire length of the mid-hepatic vein may divide the liver into the left and right lobes. The cephalic end of the left hepatic vein (about 1/4 segment) may separate the left exterior lobe and left internal lobe; the cephalic end of the right hepatic vein may separate the right anterior lobe and right posterior lobe of the liver (Fig. 4.19).

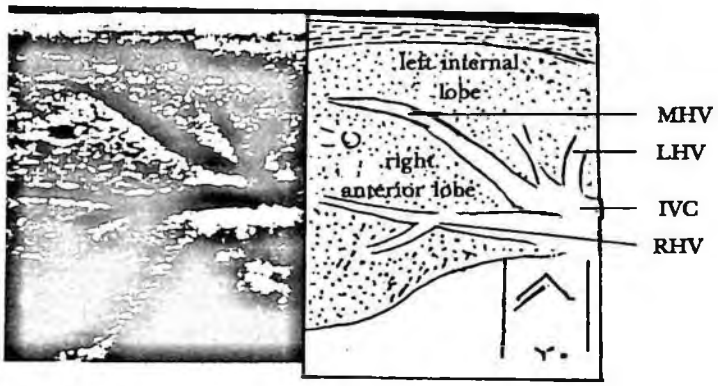

Fig. 4.19 Oblique section of the liver below the right costal margin.

4.3.1.4. *Oblique Section of the Right Intercostal Space for the Right Liver*

Examine the oblique section with a probe. At the right intercostal space (about the 7th–9th intercostal space) and the oblique section along the long axis of the portal vein, the researcher may reveal the region of the hilus of the liver, the portal vein, the extrahepatic biliary tract, and the inferior vena cava. This section is frequently used in the clinical ultrasonographic examination of the liver. But the patient should be made to lie on the left in order to expose the above-mentioned structures (Fig. 4.20).

Another section besides the above frequently used liver section is an oblique section below the costal margin of the left liver. By placing the probe below the left costal margin, parallel with it, and placing the moment of the probe towards the left shoulder, it may reveal the exterior lobe of the left liver. The second way is by placing the probe near the posterior of the right posterior axilliary line to make the coronary section of the liver. It may reveal the liver, kidney and the surrounding structures around the gall bladder. This method will increase the whole view of the liver. It is particularly useful for shrinking the liver due to cirrhosis.

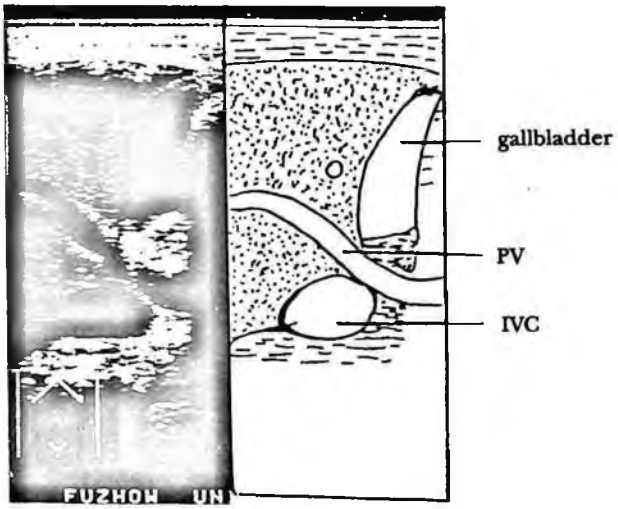

Fig. 4.20 Oblique section of the right intercostal space of the right lobe of the liver.

4.3.2. Measurement of the Size of the Liver

A normal liver has wedge shape. The morphology of the left and right livers varies greatly with the individual.

Therefore, there is a great difference among all diameter lines of the liver. At the same time, measuring all the accurate diameter of the liver is also difficult. The liver is a soft tissue. It is easily affected by the type of build, the flatulence in the gastrointestinal tract, and the fat in abdominal wall and abdominal cavity. All these factors will cause the variation of the diameter line. For instance, the left liver of a lean person will be thinner and longer, while for a fat person, his/her left liver will be thicker and shorter. Therefore, in ultrasonographic measurement, the normal figure of diameter is merely for reference. A precise measurement of the liver's diameter does not help much in diagnosis. Nowadays, there are two ways of measurement:

4.3.2.1. *Measurement of the Diameter*

(a) Measurement of the left liver.
Place the probe on the mid abdominal line inclined toward the left in front of the abdominal aorta. Measure the diameter when the upper margin of the left liver (diaphragmatic surface) and lower margin are revealed (middle of Fig. 4.21).

(b) Measurement of the right liver.
To measure the oblique diameter of the right liver, some people usually measure the thick diameter at the mid clavicular line of the right liver (anterior posterior diameter). The oblique diameter is measured with the probe below the right costal margin and parallel to the lower margin of the liver. In case the probe cannot reach the margin of the liver, the patient should lie on his left side, and allow the liver to be displaced in the left inferior direction. Then move the probe away and let the plane of sound beam point at the right diaphragmatic dome, take the farthest distance of the oblique section image

of the diaphragmatic surface of the liver from the probe as the standard measurement (right of Fig. 4.21). The measurement of the thick diameter of the right liver at the mid clavicular line is done by the longitudinal section or oblique section of the liver along the intercostal space by placing the probe perpendicularly on the right mid clavicular line (left of Fig. 4.21). There are different views about this method because measuring the real thickness is very difficult.

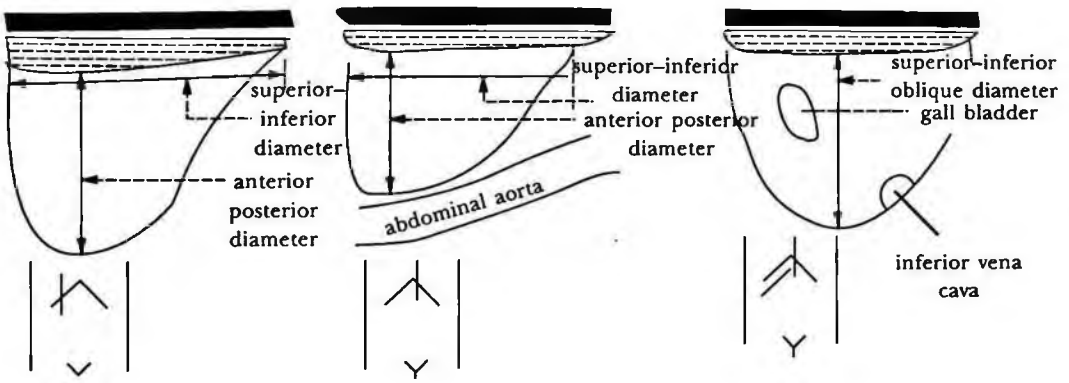

Fig. 4.21 Sketch map of the size of the liver. The right map shows the longitudinal section of the right mid clavicular line. The middle map shows the anteral longitudinal section of abdominal aorta. The left map shows the oblique section of the right subcostal margin.

4.3.2.2. *Measurement of Area By Using Electronic Measuring Techniques.*

By attaching the installation with the present ultrasonographic instrument to draw certain sections of the liver, the measurement of area can be displayed on the screen. Measuring the area of the caudal lobe in front of the inferior vena cava is the quickest method. No matter which approach, in order to reveal the standard image of the liver's section, one must get a clear, entire outline of the liver. If any linear array probe is used due to difficulty of disclosure of the diaphragmatic surface, the measurement of the vertical and horizontal diameters will be limited.

4.3.2.3. *The Value of Measuring the Liver*

There is no absolute standard of the measurement at present. Usually it is estimated that the oblique diameter of the right liver is not over 13–14 cm, the anterior posterior diameter of the left liver is about 4–7.5 cm, and the top-to-bottom diameter is about 4–8 cm.

4.3.3. Identification of Certain False Focusing in the Liver

During ultrasonographic examination of the liver, factors such as many normal anatomical structure of the liver, variable normal structures in sonographic image, artifact of the surrounding viscera around the liver, or acoustic effect may be misdiagnosed as a forged

focus in the liver. The following gives the common influential factors and the method of identification.

4.3.3.1. *The Echo of the Hepatic Ligament*

The ligaments of the liver are the falciform ligament, the round ligament of the liver, the venous ligament, the hepatogastric ligament and the triangular ligament. The falciform ligament is not commonly disclosed. Only in cases of ascites, strand-like or linear-like echo may be found between the diaphragmatic dome, anterior abdominal wall and the left lobe of the liver (Fig. 4.22). The round ligament of the liver lies on the fissure of the left lobe of the liver. It is the remaining structure of the umbilical vein in the fetal period after obliteration. On the sonographic image of the transverse section of the left liver, a small circular nodule or an irregularly strong echo bright area may cause the diameter to reach up to several micrometers. Sometimes, when accompanied with a sound image, it may be misdiagnosed for an intrahepatic space-occupying pathological change, a stone or small nodular pathological changes. The identification method is to move the probe on the image of the longitudinal section of the left liver. The round ligament of the liver is a long strand, just like a strong echo starting from the margin of the left liver (right side of image). It connects with the sagital segment of the portal vein. By using this method to identify the cross section, the round ligament of the liver can be intervened between the left internal and left external lobe of the liver (Fig. 4.23).

The venous ligament is located between the left lobe and the caudal lobe of the liver. Its echo also presents a strand-like strong echo, which serves as the landmark of the left lobe and the caudal lobe of the liver. The fissure of the venous ligament often causes the echo of the caudal lobe to become weaker, similar to the low echo area of a focus. Therefore, by changing the direction of the probe they can be differentiated.

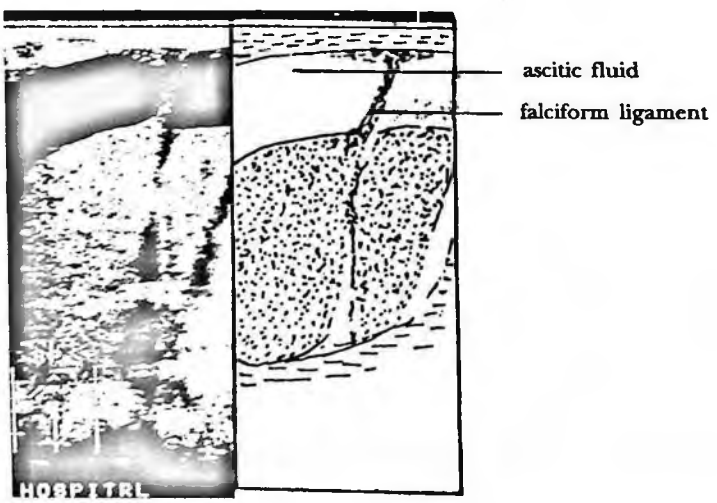

Fig. 4.22 Falciform ligament.

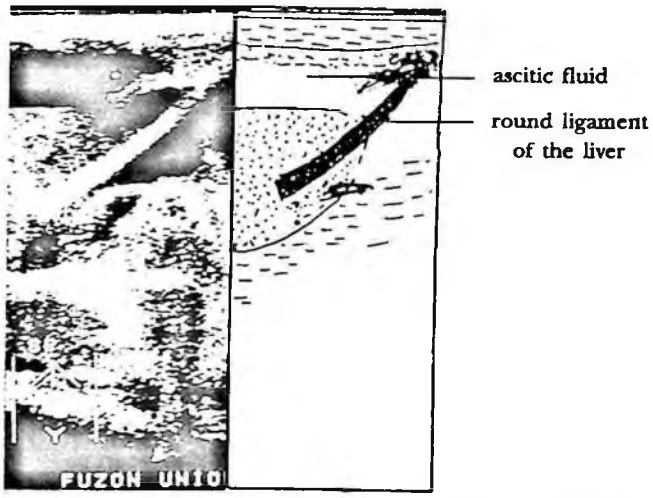

Fig. 4.23 Image of the round ligament of the liver during ascites.

The triangular ligament lies inside the costrophrenic angle. Normally, it is covered by the lower margin of the lung which cannot be revealed in a sonographic image. When hydrothorax and ascites exist simultaneously, the costophrenic angle will be filled by fluid in the chest and ascites under the diaphragm. So by placing the probe between the right anterior axilliary line and the right mid axilliary line, a linear strong echo of the right triangular ligament may be detected. This should not be misdiagnosed as a pathological change in the tissue. The hepatogastric ligament and omentum minus extend to the fissure of the venous ligament. Due to the rather strong echo, in addition to the strong echo of the tubular wall of the left branch of the portal vein, it may produce a forged image of the tumor by the low echo of the caudal lobe. It can be differentiated by changing the direction of the probe. There must be sufficient recognition of the surrounding circular structure of the caudal lobe and its relations.

4.3.3.2. *Variation of the Caudal Lobe of the Liver*

The form and size of the caudal lobe vary greatly in the course of normal life. It is usually mistaken for a lump of focus. These variations have been described in detail in the paragraph on ultrasonographic diagnosis of the liver.

4.3.3.3. *Fibrous Tissue in a Normal Liver*

Certain groups of people, especially old men, have increased strong echo of the strand-like structure. This effect is found inside the liver. This might be the echo of fibrous tissue, which have been proven by examination to be due to a normal phenomenon, and should not be mistaken for focusing inside the liver. Furthermore, the echoes of the vascular wall or capillary wall inside the liver increase in strength, many short, linear or equal (=) sign strong echoes can be seen in the sonographic image of the liver's cross-section, but most of them

are without any chemical significance. After changing the direction of the probe, resources follow up the equal echo connected with the long axis of the lumen.

4.3.3.4. *Structure and Focus of the Visera Around the Liver*

The visera around the liver, for example, fat around the kidney, the antrum of the stomach, the supper pole of the right kidney, the shadow of the ribs, fat surrounding the front of the liver, and subphrenic may be misdiagnosed as an intrahepatic focus due to lack of experience during sectioning, or lack of identification of the image. One must pay attention to the above.

4.3.3.5. *Acoustic Effect and Artifact*

In a sonographic image, the appearance of normal parenchyma has connection with many factors, such as the resolving power of the ultrasonographic apparatus, frequency of the transducer and the repeat frequency of the pulse. It has a connection with the depth of focusing of the beam and other factors. In general, when there is a high-frequency, short pulse (weak echo of parechyma of liver) and proper focusing of the depth, the image is clear. Many acoustic effect and artifact also influence the analysis and diagnosis of the ultrasonographic image. Sometimes, researchers may mistake an artifact for a focus, so they should pay attention to the side lobe:

(a) Multiple echoes and side lobe artifact
During examination of the gall bladder and portal vein, it is often found at the bottom of the gall bladder, or above the margin of the neck of the gall bladder. Inside the portal vein, there is a coarse cloudy echo which could be the sedimentation of bile clay or thrombus inside portal vein. The artifact is actually produced by the side lobe of the beam. Sometimes, strand-like strong echoes are found in the common bile duct or portal vein. Usually, the second echo of the tubulac wall that will disappear after changing the direction of the probe.

(b) Artifact induced by the volume effect
Since the ultrasonic beam can possess thickness, or has a "volume effect", during a clinical sectional examination of the liver (such as oblique section below the right costal margin section of partial wall) the bladder can be revealed inside the liver. Sometimes, it is mistaken for space-occupying pathological changes inside the liver, particularly when the gall bladder wall is thick, or when the strong echo hyperechogenic mass overlaps inside the gall bladder due to flatulence inside the duodenum (that will be mistaken for cholecystolithiasis).

Therefore, for the ultrasonographic sectional image of the liver, one should notice the volume effect induced the overlapping of the image of the margin of a nearby organ.

(c) False image by the presence of ascites
As discussed in the chapter of ultrasonographic diagnosis, there are many types of expressions owing to good transmission of sound by ascites. Let the energy capacity of ultrasound (without attenuation) enter the borderline of medium posterior. It will produce a strong reflection, resulting in a very bright image and increase of the

thickness and strength of the light dots. Thus, one can misdiagnose a normal liver with ascites as cirrhosis of the liver due to ascites.

The distinction may be based on whether the surface of the liver is smooth, whether there is dilatation of the portal vein, whether the spleen is enlarged, and other clinical data.

(d) Artifact due to the maladjustment of instrument

A sonogram usually produces an echo when the focusing is strong. In the case where the near-field and far-field adjustment of gain is relatively insufficient, a false incrass echo in the intervened region may be produced. Improper adjustment of gain will produce relative increase or decrease of the echo at the near-field or far-field, resulting in a false diagnosis. For different instrument and different frequency, the method of adjustment is different also, the standard lies on even sonograms in all regions.

(e) Another artifact

Besides the above-mentioned artifact, there is a false image connected with attenuation of sound, such as the sound image of the tubular wall of the portal vein. It may be mistaken for a stone inside the liver, or another artifact due to reflection of the great bordered surface. In this case, it should be treated seriously.

When identifying a normal sonogram, one must pay attention to the tissue structure of the liver itself. Poor instrument, improper adjustment, acoustic effect and the presence of artifact will cause false focus. Even though there are all sorts of expressions, careful observation and analysis of sound images, through the standard manipulative methods are closely associated with clinical and other related data with image and laboratory examinations. Thus, it is not difficult to differentiate between them.

4.4. ULTRASONOGRAHIC DIAGNOSIS OF COMMON DISEASES OF THE LIVER

4.4.1. Space-Restricted Pathological Changes in the Liver

A space-restricted pathological change is usually considered the most important indication in the ultrasonographic examination of the liver. It is important in the diagnosis of tumors in the liver, pyogenic inflammation, and cyst.

4.4.1.1. *Cyst in the Liver*

(a) Clinical and pathological

A cyst in the liver is one of the more commonly seen "space-occupying" pathological change in the liver. Clinically, they may be congenital or acquired. The latter can also be divided into parasitic and non-parasitic. A congenital cyst in the liver is commonly called a polycystic liver. About 50% of the cases are accompanied by a polycystic kidney, or cysts in other viscera. Its characteristic is inside the liver. There are many different sized oval, thin-walled cysts. The cyst lumen is filled with clear fluid, and is commonly seen in patients after 40 years of age. It is not easily discovered at the early stage. Patients tend to seek treatment only when the cyst has become larger, with a mass which

appear in the upper abdomen, and when the liver only is enlarged. Sometimes, the cyst may cause abdominal pains and jaundice. A single cyst is called a cyst in the liver. It is mostly seen in middle-age and old adults. A female is four times more likely than a male to have this problem. The size of the cyst varies; its diameter is 5–20 cm. It is usually located at the lower part of the right lobe of the liver. Sometimes, 2–3 cysts coexisted. They contain serous fluid, which is mostly embraced with dense fibrous tissue. An echinocciasis cyst is the ova of the echinococcus (echinococcosis) living in the human liver. It is mostly found in pastoral areas.

(b) Appearance in the sound image

In the sectional image of the liver, there is one or many round, or oval, echoless dark areas. The outline border is clear and smooth, and has a distinctive cystic wall echo. Its internal echo is mostly an echoless, fluid-type dark area. Part of it may have dot-like or cloudly laminated echo. It may have a polylocular separation. The anterior wall of shallow located the cyst, and the echo is not clear due to many times echo or it apppears to laminate hazy strand-like, or cloudy, echoes. The echo of the posterior wall is increased and the strengthening, effect is seen in deep-seated cysts.

Both sides of the cyst appears to be able to reflect the sound shadow laterally. A seated, shallow big cyst often becomes compressible with pressure by real time ultrasonic probe.

The volume of the cyst of the liver varies greatly. Its pressure on the surrounding parenchyma of the liver and blood vessel, and its influence on the local outlook of the liver differs significantly. An outward growing cyst may be mistaken for a cyst of an organ around the, liver. When the cyst of the liver is complicated with hemorrhage or infection, diffusive, minute echogenic dots may be found in the echoless area of the cyst; the cystic wall may increase, and appear hazy (not clear), with an irregular margin, it cannot be easily distinguished from the abscess of the liver. Sometimes, repeated examinations are needed to obtain the correct diagnosis. The liver of the polycystic liver is, in general, enlarged. Both the left and right sectors of the liver are scattered with different sized cystic bubble-like structures. Its diameter varies from several millimeters to several centimeters. The normal liver tissue and structure of the intrahepatic biliary tract are not clearly disclosed. The polycyst in the liver is usually accompanied by polycyst in the kidney. Ultrasonographic diagnosis for echinococcous is conducted by finding a daughter cyst inside a big cyst. Sometimes, one may find a strong echoing wall due to the calcification of the cystic wall. In this case, the cyst become denatured. Increasing echogenic dots inside the cyst may be found similar to a substantial tumor. The x-ray plane film of the abdomen and CT examination are helpful in the diagnosis of the calcified echinococciasis of the liver. It should be combined with the history of the epidemiology and Carini skin hypersensitivity test in order to differentiate them from a congenital cyst or retention cyst (Figs. 4.24–4.25).

Many ultrasonographic diagnosis for a cyst in the liver have very high sensitivity and accuracy of 98%. But, there are some other non-typical cysts in the liver, such as a cyst with infection, or a cyst with too small a cyst volume. In a complicated case of the polycystic liver with very small cysts, the echo of the entire liver increases diffusively, and the tiny cysts can be easily missed out during diagnosis. In addition, the following conditions should be differentiated:

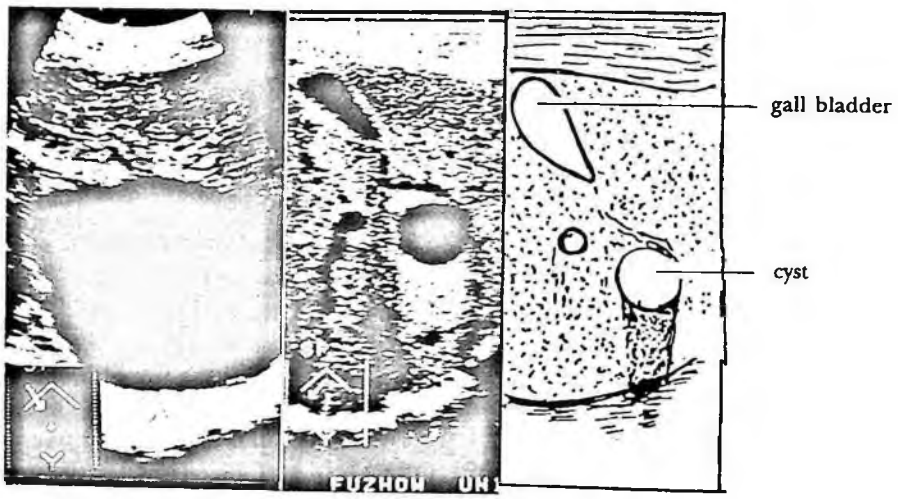

Fig. 4.24 Left figure shows big cyst in the right posterior lobe of the liver; middle and right figure shows a small cyst in the right anterior lobe of the liver.

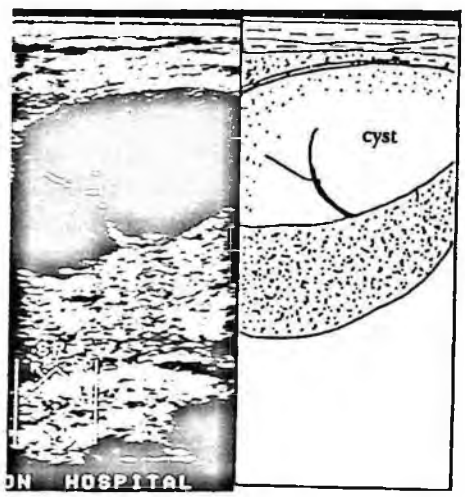

Fig. 4.25 Cyst in the right anterior lobe of the liver and the intervening spaces.

(a) Congenital dilatation of the biliary tract in the liver (Caroi Disease)
This is an uncommon congenital disease in the liver with a typical expression of segmental dilatation of the biliary tract in the liver, similar to a cyst. However its running direction is identical with the biliary tract in the liver, without any fibrotic changes in liver.

(b) Dilatation of the venous sinus in the liver
Sometimes, a solitary cyst in the liver may be confused with the dilated venous sinus; but small cysts are usually round, and the echoes are even and has a thin wall. By changing the direction, the venous sinus will be presented in the form of a long strip. One can also distinguish a strong echo of the wall.

(c) Congenital fibrosis of the liver complicated with dilatation of biliary tract in the liver, cysts in the liver and kidney

It may be hereditary. Its typical expression is the enlargement of the liver and spleen, and portal hypertension. The echo of the liver diffusively increases similar to the cirrhosis of the liver. This disease should be particularly differentiated from the polycystic liver, with very small cysts inside the liver. This disease is mostly seen in infants and children. It is occasionally found in teenagers.

(d) Abscess of the liver

The abscess of the liver is easily distinguished from a cyst in the liver, but a highly liquified abscess is sometimes difficult to distinguish. A cyst in the liver must be examined with the case history together with other laboratory examinations. The morphology of the abscess of the liver is usually irregular. It is surrounded by a low echo area due to inflammatory reaction (Fig. 4.26).

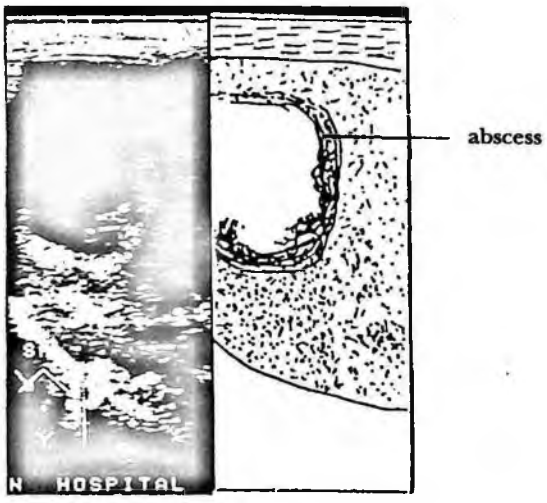

Fig. 4.26 Abscess of the liver.

4.4.1.2. *Abscess of the Liver*

(a) Clinical and pathological

A liver abscess is mostly infected by bacteria. Amoeba, protozoan and actinomycosis are mostly transmitted by blood, and is not commonly determined by retrogressive infection from the biliary tract. Sometimes, it is caused by direct invasion of a nearby inflammation, such as perforation of the alimentary tract, pyogenic peritonitis, subphrenic abscess or perirenal abscess. Frequent diseases of the biliary tract is one of the direct causes. Bacterial abscess multiple focus, amaebic abscess of the liver is usually a single big abscess complicated with amaebic dysentery (2%–10%). Inside the baterial abscess of the liver, there are usually necrotic tissue and cellular fragments. In there, inflammatory reaction around it increases the connective tissue; while amaebic abscess of the liver usually occurs in the right lobe of the liver. Inside the abscess cavity are necrotic tissues and a mixed fluid of necrotic tissues and old blood. Its wall is attached

with incompletely necrotic liquified connective tissues, blood vessels and the biliary tract, somewhat like cotton fibre.

(b) Expression of the sonographic image

A typical abscess of the liver has the following expressions:

(i) Single or multiple liquified dark area of low echo inside the liver, with different size and form, or somewhat round; the outline is mostly unclear; the demarcation with a normal liver is not as clear as the cyst of the liver.

(ii) Around the abscess of the liver there is a several millimeter thick circular flow echo area zone associated with the reaction of inflammation in the surrounding.

(iii) The posterior wall of a deep-seated abscess of the liver may have a "strengthening effect", but it is usually not so remarkable as a cyst.

(iv) Inside the abscess cavity, there is a floating, tiny light dot which moves with the body. Sometimes, exposed laminated images may find a rather big, bright light dot at the lower part of the dark area. Tiny and comparative granules are scattered in the middle layer, and the upper layer contains thin pus fluid; it is the typical characteristics of the function at the gravity force of the abscess cavity, so withdrawing pus by puncture into the abscess cavity under the guidance of ultrasound is contradicated by puncture into the lower layer of the abscess cavity, in order to avoid the obstruction of needle's head (Fig. 4.27).

(v) Other signs: the shallow-seated abscess will cause localized swelling of the liver, protruding out and causing deformity.

A rather large abscess will limit the movement of the diaphragm. In many of them, the right hydrothorax is found. In many patients, the primary focus in the biliary tract may be found.

The non-typical appearance of the ultrasonographic image of an abscess of the liver

Fig. 4.27 Abscess of the liver inside the abscess cavity, showing floating echoic dots.

(i) Early stage of a liver abscess

In the local congestion of a focus, or edema at the stage of inflammatory infiltration, or incomplete necrotic liquefaction, the sonogram shows a low echo area of increased transmission of sound or appearance of localized hyperechogenic mass that should be differentiated from the carcinoma of the liver, and lymphadenoma. It is generally considered that the liquefication of an abscess of the liver appears in 8–14 days during the course of illness (Fig. 4.28). By combining many follow up examinations with clinical diagnosis, the necessary withdrawal of pus by puncture under the guidance of ultrasound is helpful in diagnosis.

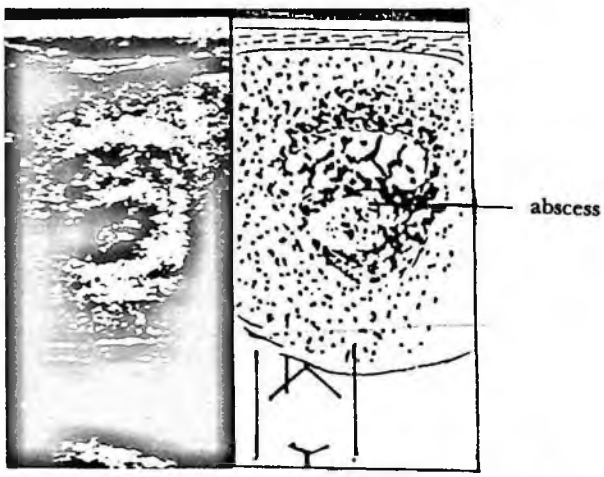

Fig. 4.28 Early stage of the liver abscess.

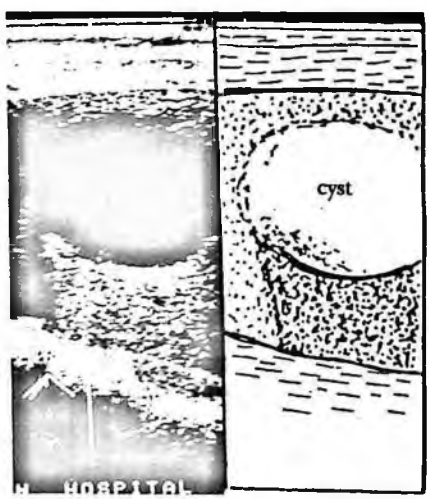

Fig. 4.29 Cyst in the liver complicated with infection, showing floating echoic dots inside.

(ii) Multiple abscess is mostly developed by bacterial infection
There is no typical expression in ultrasonographic image: more often the appearance of an enlargement of the liver, diffusive increasing rough and uneven echo in the liver, and sometimes one can find a scattered, small abscess cavity.

(iii) Cyst in the liver complicated with infection
Owing to infection on the basis of the cyst in the liver, its sonogram may reveal a complete cystic wall, with floating light dots inside (Fig. 4.29).

(iv) The healing stage of the abscess of the liver
The course of the disease is rather long, and the abscess of the liver tend to heal gradually. Granulation tissue grows into the abscess cavity, pus is gradually decreased, and eventually disappears. Inside the cavity, the boundary surface is complicated. In the sonogram, one may find localized, scattered light dots, or hyperechogenic mass, the boundary is also unclear.

(v) Chronic thick wall abscess of the liver
Pus in the abscess cavity is sticky, contains many things, and the wall of abscess cavity is not smooth. After formation of granulation tissue, there is adhesion with the surrounding tissues. The sonogram usually presents a substantial light patch or hyperechogenic mass. The wall of the abscess cavity is thick and strong; the echo may be strong or weak, and equal or unequal echo inside the abscess cavity can be easily confused with a tumor (Figs. 4.30–4.31).

(c) Differential diagnosis of the liver abscess. In general, the ultrasonographic diagnosis of an abscess of the liver is not difficult, but it must be distinguished from other space-occupying lesions in the liver, such as low echo inside the liver in the case of a tumorin liver, liquefaction of the carcinoma of the liver, non-typical polycystic liver cyst in the liver complicated with infection, or hematoma within the liver (Table 4.3). Sometimes, it must be differentiated from the lesion surrounding the liver, such as subphrenic abscess, pseudo pancreatic cyst, right renal cyst, perirenal abscess and abscess in the upper abdominal wall. The majority of cases of intrahepatic lesion can be differentiated by a careful examination, combined with the case history and laboratory finding. Extrahepatic lesions can be applied to multiple direction and multiple position of the body for examination by observing the movement of tumor mass with the liver. In this case, by making a longitudinal section on the xyphoid at the upper abdomen, and by asking the patient to breath deeply, we can see the movement of pseudo pancreatic cyst, which does not coincide with the movement of the liver.

4.4.1.3. *Tumor of the Liver*

The tumor of the liver includes malignant and benign tumors. The former is further divided into primary malignant tumor and metastatic tumor. Ultrasonic imaging has a definite value in early discovery of tumors in the liver such as small hepatic carcinoma, and it can provide valuable clues in the differential diagnosis of tumors. If combined with small needle puncturing cytological and histological examination under the guide of ultrasound, it will greatly raise the accuracy of diagnosis.

Fig. 4.30 Big chronic thick-walled abscess of the liver.

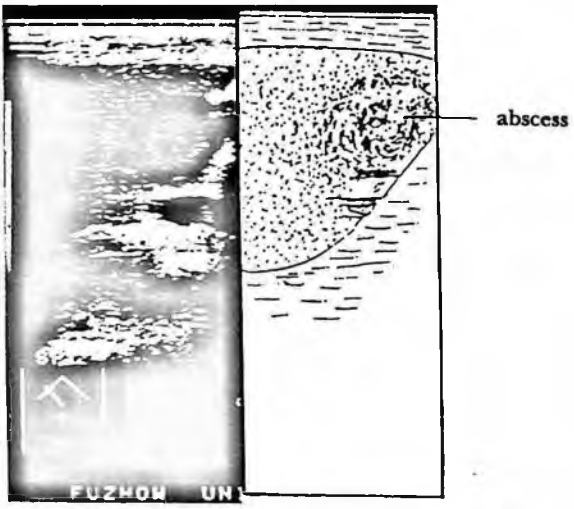

Fig. 4.31 Small chronic thick-walled abscess of the liver.

(a) Malignant tumor of the liver

(i) Clinical and pathological

Malignant tumor of the liver can be divided into primary tumor and metastatic tumor. The commonly seen of the former is primary hepatome, cholangiocarcinoma, and mixed carcinoma of liver. Primary hematoma is further divided into diffusive type, multiple nodular type, nodular mass type, single mass type, and small carcinoma type, in accordance with the pathology. A diffusive type tumor presents minute nodules diffusively distributed in the liver, it possess an unclear boundary and undergo infiltrative growing. Multiple nodules type tumors presents many different sized

Table 4.3. Differentiating the Sonograms of the Liver Abscess and that of Other Diseases in the Liver

Item	Liver Abscess	Liquefaction of the Carcinoma of the Liver	Hepatic Cyst
morphological outline	outline mostly round, unclear	irregular, outline usually unclear	clear, round outline
internal echo	no or scattered light dots or echogenic mass	irregular, or no light dots	even or no light dots, good transmission of sound
surrounding echo	normal liver tissues presenting tiny light dots	mostly strong hyperechogenic masses encircled by an echolesss dark area	tiny light dots of normal liver tissues
echo of the posterior wall	great increase	not obvious	becomes more obvious
echo at the distal end of the posterior wall	slight increase	not obvious	becomes more obvious
shadows of both sides	slight inner received shadow	dispersed shadow, or absence of shadow	marked inner received shadow

nodules, with diameters between 3–5 cm, it has a clear boundary and is usually accompanied by cirrhosis of the liver. Nodular mass tumor is the most commonly seen one. The diameter of its mass is usuallly within 5–10 cm. Many nodules combine together to form a rather big carcinomatous mass, similar to a "giant-mass-type" tumor; a single mass type tumor presents a single nodule or a giant mass. The biggest diameter may reach beyond 10 cm, and contains a capsule in which its intrahepatic tissue is often crushed. A small carcinoma of the liver usually presents a single small nodule, often with a diameter within 3 cm. The boundary may be clear, and often contains a capsule. Cholagiocarcinoma is seldom seen. It is also divided into giant mass type, nodular type and diffusive type. The mixed type is more seldom seen.

The metastatic tumor of the liver comes from a malignant tumor of many viscera in the whole body, among which the most common seen is the digestive system, after which comes the malignant tumor of lung, breast, and pelvic cavity. A metastatic tumor of the liver usually invades the whole liver, and usually presents a small nodular or diffusive type, which only 10% of metastatic, carcinomatous nodule of the liver is single. Its pathological feature is the nodule-presenting drum-

like prominence beneath the capsule of the liver. Its central portion is often sunken concavely from necrosis or fibrous contraction.

(ii) Sonogram image expression of a malignant tumor

(1) Abnormal outline and morphology

According to the macroscopic pathological change, the sonogram is divided into the giant mass type, nodular type, diffusive small nodule type (or nodular mass type), diffusive type, and small carcinoma type. The liver usually loses its normal form; its margin is round, obtuse or bulging. Sub-capsule growing carcinoma of the liver, the localized hyperechogenic mass will induce an outline of the liver, and the corresponding part of the diaphragm protrude as a "camel hump sign", resulting in the angle of lower margin of liver becoming bigger. In particular, the left lobe of the liver will change more distinctively. The above-mentioned sign is not seen in small or deep tumors. The volume of the liver is usually enlarged. In the parenchyma of the liver, nodular-like or mass- like echo appears with various form; some are round shape, oval shape, lobular shape, or irregular shape. When growing as crab foot, the boundary becomes either clear or hazy.

(2) Internal echo is complicated, and undergoes various changes

Owing to many pathological changes of the maligant tumor of the liver, the internal echo of the sonogram is also not identical, and its expression is as follows:

Enhancement of the echo type

Some may express mild enhancement of the echo, the texture is even, and may be related to more vascular and interstitial components. Some may express marked enhancement of the echo, and a non-homogeneous texture is mostly seen (Fig. 4.32).

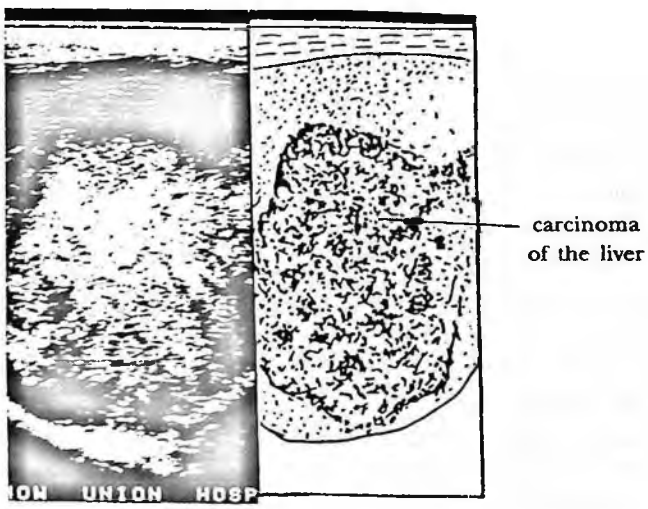

Fig. 4.32 Carcinoma of the liver (enhancement of echo type).

Equal echo type

The density of the tumor echo is equal to the surrounding liver tissue, but it has a definite demarcation with the normal liver tissue. It should be observed carefully, and combined with other features of a sonogram image in order to avoid mis-diagnosis (Fig. 4.33).

Echo weakening type

In general, the texture is rather even and is commonly seen in a small volume carcinomatous nodule (Fig. 4.34).

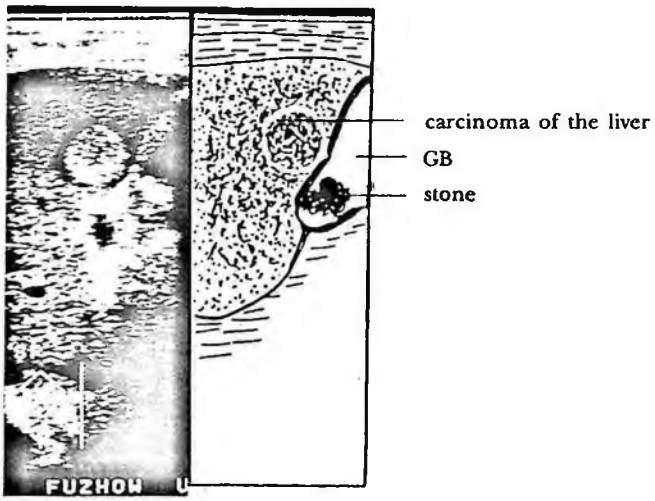

Fig. 4.33 Carcinoma of the liver (equal echo type).

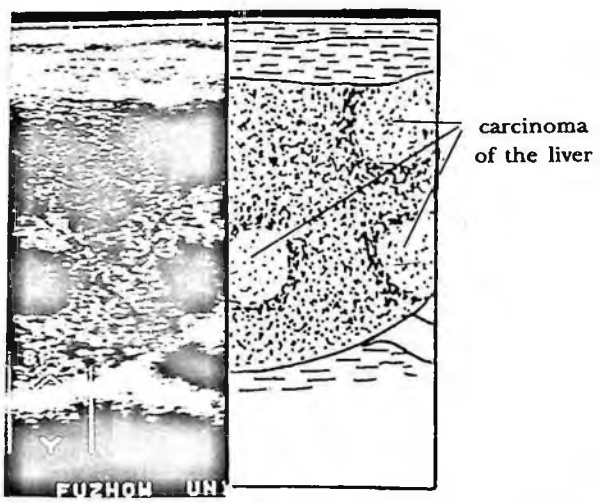

Fig. 4.34 Carcinoma of the liver (weak echo type).

Echoless type

Mostly found in lymphosarcoma or lieomyosarcoma. The echo is homogeneous. The demarcation with a normal liver tissue is still clear (Fig. 4.35).

Cystic change type

A small patch, or rather big echoless area usually appears within the liver tumor, or it may have a big volume. It mostly indicate rapid growing of the tumor leading to central liquefied necrosis, presenting a change in the sonogram of the mixed tumor. If liquefaction is marked inside the tumor, it will be similar to a cyst, such as necrosis inside the primary hematoma, with a large amount of hemorrhage (Fig. 4.36).

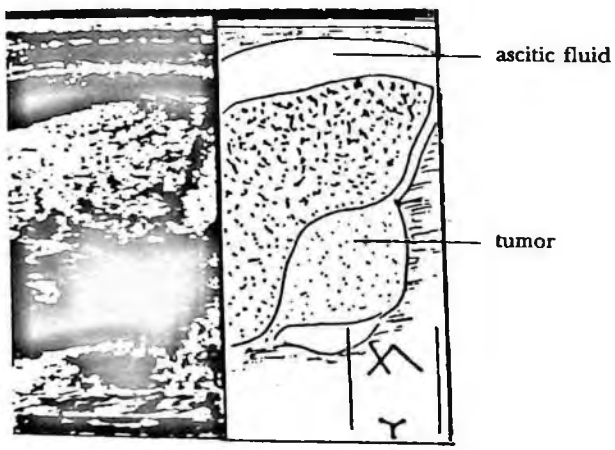

Fig. 4.35 Carcinoma of the liver (echoless type).

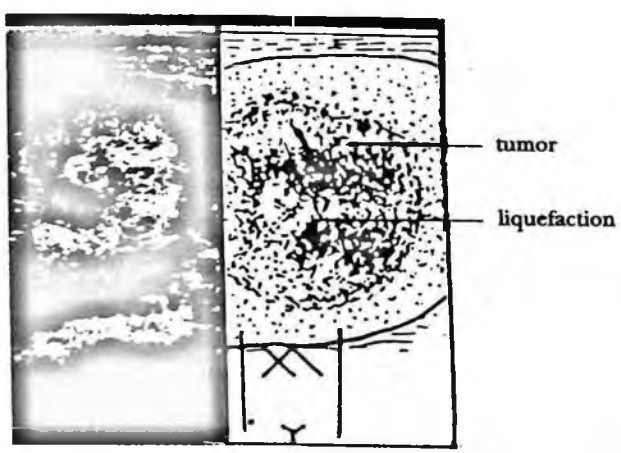

Fig. 4.36 Carcinoma of the liver (liquify type).

Special change of form type

The surrounding of the central ischmic necrosis of the tumor nodule of the liver is a still, solid echo of even texture, forming a target-like image (Fig. 4.37).

It is worthy to mention that even the expression of the sonogram of the tumor of the liver has a definite relation with pathological changes. There are many factors which will influence the sonographic image. The result from the expression of the image will not be entirely identical to histological variation. For instance, with the same kind of liver tumor, the expression of the sonogram may not be the same. It will increase to multiform and complicate the expression of the sonographic image. It is also a problem that deserves attention during the ultrasonic diagnosis of a liver tumor.

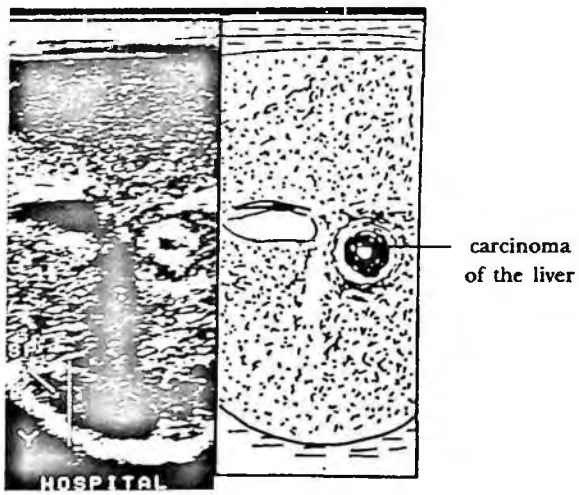

Fig. 4.37 Carcinoma of the liver (target type).

(3) "Sound halo", "light wheel", "marginal vascular sign", and other marginal echo sign.

Expression of marginal echo of the tissue from the tumor of liver also varies. A very thin layer of echoless band, called the "sound halo", around the tumor nodule is often seen. Some people regard it as the scattering and refraction of the surface echo of the tumor, or the infiltrative growth of the surrounding of the tumor. Nevertheless, the mechanism is still unsure. In addition, along the anterior side of the tumor tissue, there appears a lunar halo- or solar halo-like enhancement of the echo area, called "light wheel" (Fig. 4.9). Owing to the coarseness of the tumor surface, a great difference in the acoustic impedance of interface occurs. Owing to the space-occupying lesion of the liver, the sign of vascular detouring is often seen inside the liver, such as when the hepatic vein or the portal vein is suddenly interrupted or elevated by the tumor, or coiled over its margin. In addition, the cross-section of a branch of the small vein at the margin of the tumor is similar to small equal "=" sign or

the typical marginal vascular sign of the cross-section of a small rounded blood vessel (Fig. 4.38).

(4) Oppression sign of the intrahepatic tract

A tumor often oppresses the intrahepatic vascular and biliary system. The oppression of the hepatic vein or the portal vein is often seen; the oppression of the portal vein will cause dilatation of the portal system at its posterior end (Fig. 4.39). The spleen will be enlarged. If the tumor oppresses a branch of a big bile duct, it will cause the dilatation of the small bile duct at its distal end. If the tumor oppresses the hilus of the liver, extensive dilatation of the intrahepatic duct in the liver will occur, thus presenting "stelliform" (Fig. 4.40).

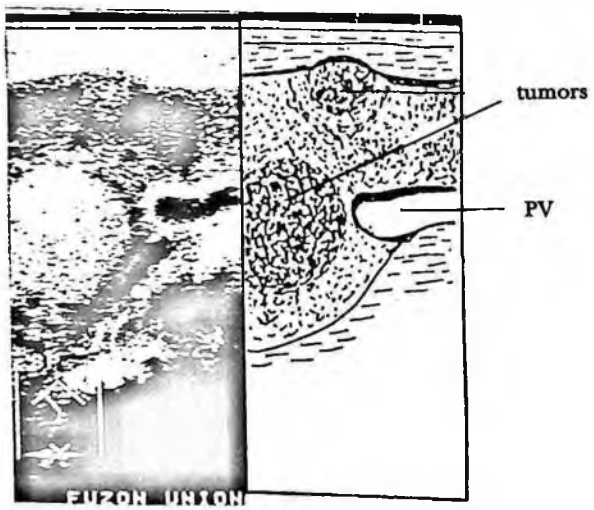

Fig. 4.38 Carcinoma of the liver (oppression of the portal vein — sign of sudden interruption).

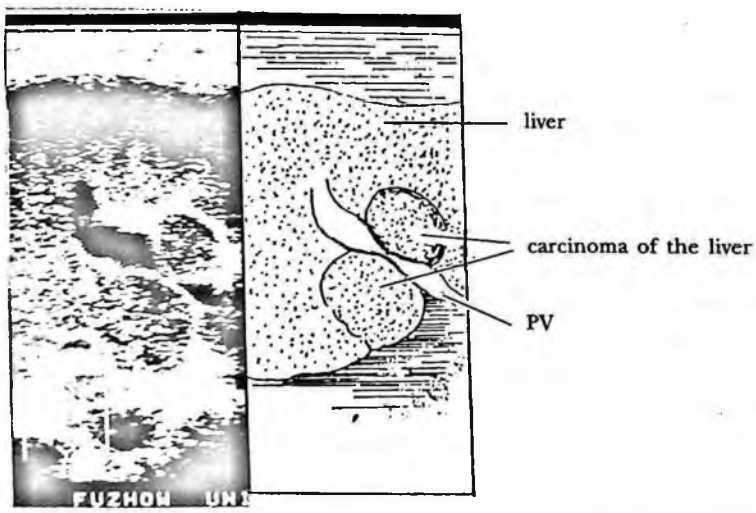

Fig. 4.39 Carcinoma of the liver and oppression of the portal vein.

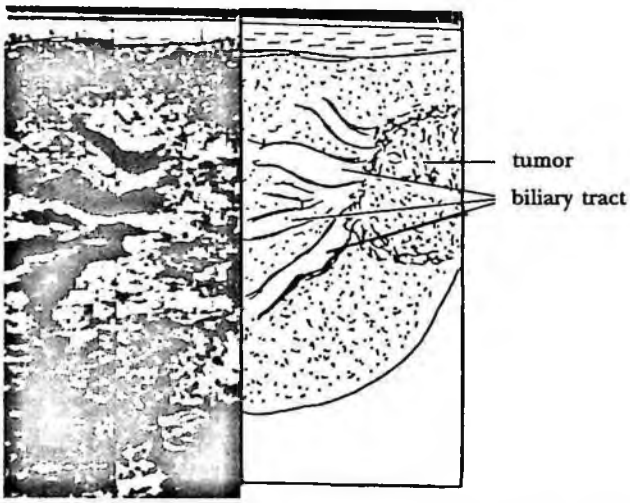

Fig. 4.40 Tumor of the hilus of the liver inducing dilatation of the intrahepatic biliary tract.

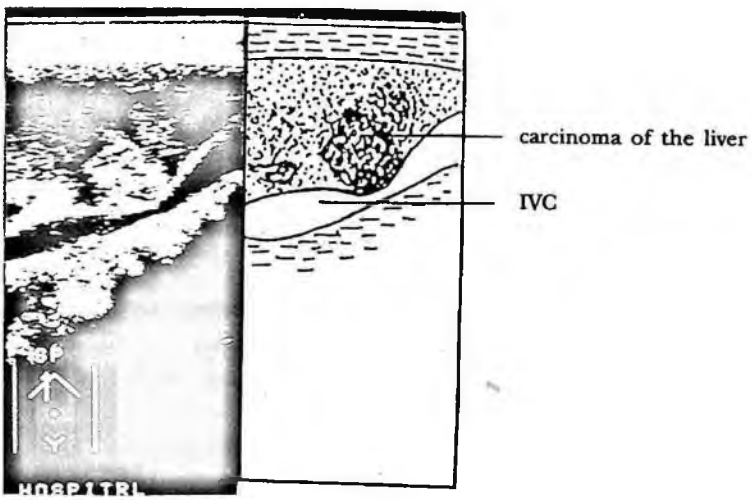

Fig. 4.41 Narrowing of the inferior vena cava due to oppression by the carcinoma of the liver.

(5) Sign of the involvement of the surrounding viscera
The surrounding viscera involved by a liver tumor will induce corresponding changes, such as elevation of the diaphragm or irregular localized prominence, metastasis to, or oppression, of the gall bladder tumor, narrowing of the inferior vena cava due to oppression, metastasis of the lymphnodes of the hilus of the liver, and displacement of the right kidney (Fig. 4.41).

(iii) To express the sonographic image from the primary carcinoma of the liver
The expressions of the sonographic image of the primary carcinoma are variable. The most commonly seen is the enhancement of echo type, which is further divided into nodular type of strong hyperechogenic mass, confluent type with

strong hyperechogenic mass, capsular type of strong hyperechogenic mass, and giant mass type with strong hyperechogenic mass. The image of another type, such as echo weaken type, equal echo type, mixed type, diffusive type, liquefied type (cystic type), may be found in different cases. Sometimes, they may have more than two sonographic images. A small carcinoma with echo weakening type or target type, may have enhancement of the echo type. If the primary carcinoma of the liver originated from the cirrhosis of the liver, it will be accompanied by cirrhosis of the liver or portal hypertension (Figs. 4.42–4.45).

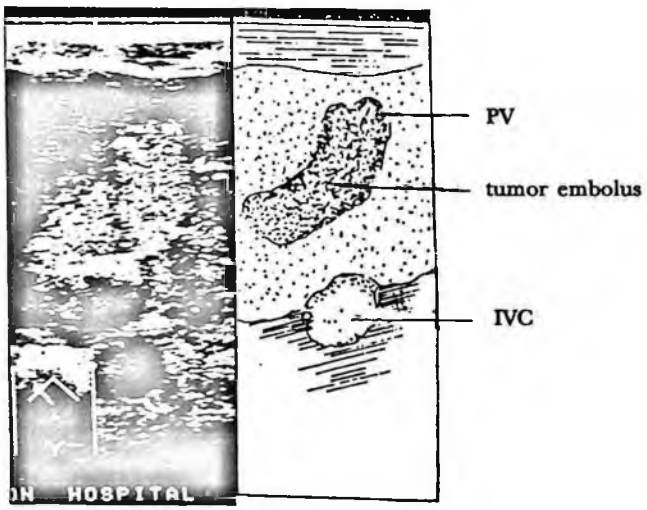

Fig. 4.42 Carcinoma of the liver, tumor embolus in the left branch of the portal vein.

Fig. 4.43 Giant-mass-type carcinoma of the liver.

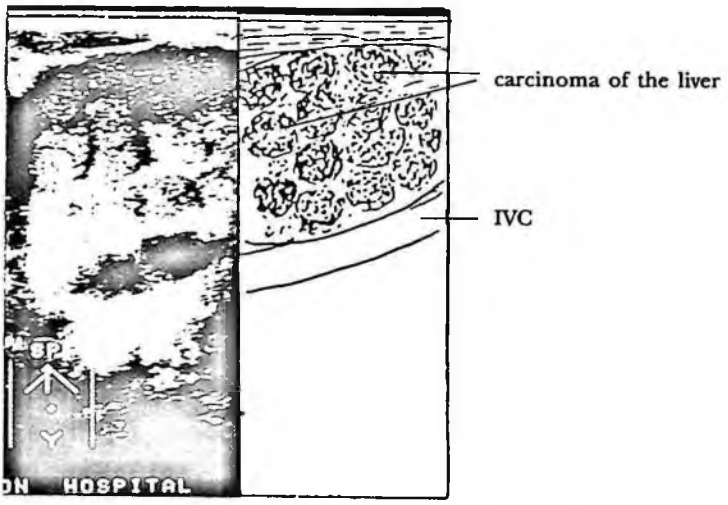

Fig. 4.44 Nodular-type carcinoma of the liver.

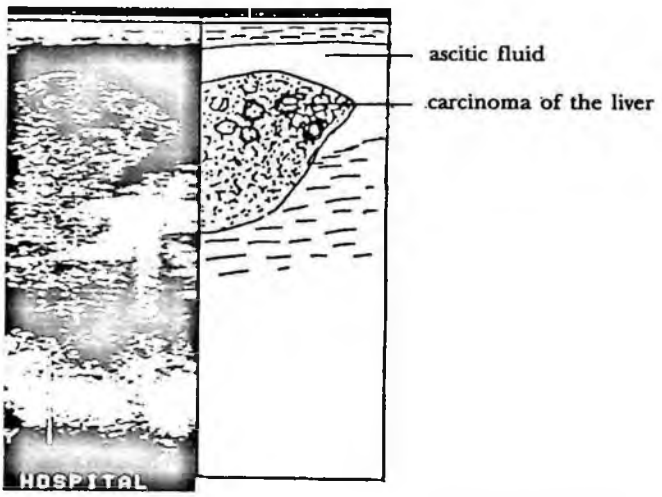

Fig. 4.45 Malignant change of the cirrhosis of the liver.

(iv) Expression of the sonographic image of the secondary (metastatic) tumor of the liver

According to the pathological characteristic of the metastatic tumor, the expression of the sonographic images have much variety. The metastatic carcinoma of the liver, in general, has the following characteristics:

(1) There maybe scattered, similar sized nodular echo inside the liver;
(2) The echo of the tumor present a low-level echo type, or a typical bull's eye type;
(3) The volume is rather small, but certain metastatic carcinoma of the liver also present a strong echo type or nodular confluent hyperechogenic mass type. Therefore, it should be combined with other signs and clinical data before analysis (Fig. 4.46).

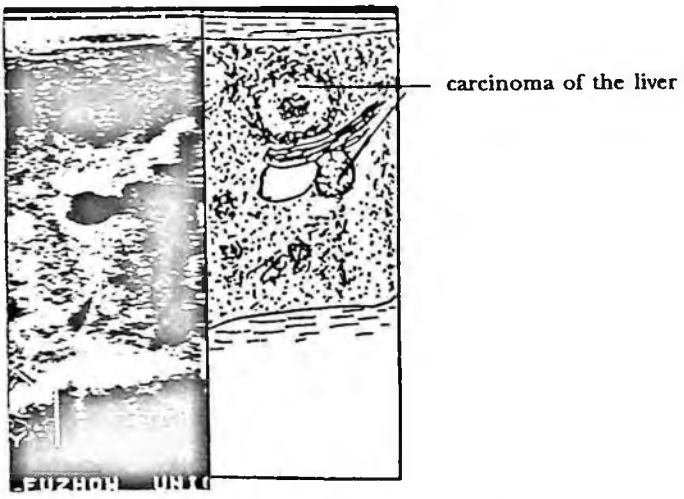

Fig. 4.46 Metastatic carcinoma of the liver (Bull's eye type).

(v) Differential diagnosis of the maglignant tumor of the liver

The above expression of the sonographic images of the malignant tumor of the liver is only the general characteristic. At the same time, there are many other influential factors, leading to a more complex, difficult diagnosis. The following differential diagnosis should be considered:

(1) Another space-occupying lesion in the liver, such as the early or inflammatory stage of abscess of the liver, or the healing stage of the abscess of the liver. Liver tuberculosis and hemangioma of the liver can be mis-diagnosed as the malignant tumor of the liver. It should be based on the characteristics of the sonographic image, and combined with clinical and laboratory finding for differentiation.

(2) Diffusive type carcinoma of the liver should be differentiated from the cirrhosis and other diffusive diseases of the liver. The sonographic image of the diffusive type of carcinoma has the following characteristics: diffusive enlargement of the liver often accompanies an abnormal outline, for example, it may be unevenly embossed, and the lower margin becomes obtuse. Parenchymal echo inside the liver is disorderly and markedly unevenly, coarse or fine small nodular changes may also be found. The vascular echo inside the liver decrease, is hazy, and unclear, otherwise it twists or undergoes displacement. There is the sign of secondary changes in the tumor in the liver. By all these, one will be able to differentiate from the cirrhosis of the liver, or from fatty liver (Fig. 4.47).

(3) Extrahepatic space-occupying lesion: the tumor of the viscera surrounding the liver is mis-diagnosed as the intrahepatic tumor, such as the tumor of the upper pole of the right kidney, and the right suprarenal tumor. The giant pancreatic tumor of the gall bladder may be examined from different directions and body positions, in order to understand the relationship between the tumor and the liver.

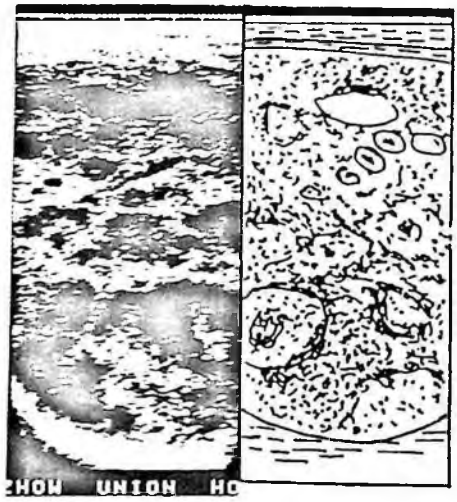

Fig. 4.47 Diffusive carcinoma of the liver.

(4) Intrahepatic false focus, such as hypertrophy of the caudal lobe of the liver, the structure of a round ligament at the liver, the acoustic effect and artifact.

(vi) Ultrasonic imaging diagnosis of the small carcinoma of the liver

The small carcinoma of the liver, in general, is referred to a tumor whose diameter less than 3 cm. It is usually mis-diagnosed by a non-typical clinical expression and laboratory examination. It mostly presents solitary or echo weakening type. Therefore, it should be examined carefully. Notice the easily neglect areas such as the right diaphragmatic dome, or the right posterior lobe. The following method may be applied to observe the small focus:

(1) Ask the patient to breathe steadily and fix the direction of the sound beam (probe). Allow the liver to move to and fro below it. Through dynamic observation, the small focus can be more easily detected.

(2) Ask the patient to hold his breath temporarily, then move the plane of the sound beam laterally in order to observe the relation between the focus and the normal tissue.

(3) From many directions and sections to prove the existence of focus.

(4) Apply post-disposal equipment, to make the focal echo more prominent.

(5) Re-check and follow up within a short duration, understand the condition of focus, and make the diagnosis is accurate.

(b) Benign tumor of the liver

The benign tumor of the liver are hemangioma, harmartoma, adenoma, fibroma, lipoma and myxoma. Among them, hemangioma of the liver is common. Most of them induce no marked symptom, and are discovered only accidently. Owing to different pathological basis, the expression of the sonographic images varies greatly.

(i) Cavernous hemangioma of the liver: this type of tumor usually grows beneath the capsule of the liver. It may be found in the deep-layers of the liver, from several millimeters to several centimeters deep, but it is mostly present as big nodule or a giant mass type (diameter may reach more than 10 cm). The boundary of the

tumor is clear and soft. Inside the tumor, there are cavernous spaces filled with blood. Sometimes, it may develop fibrosis, causing blockage of the space. The expression of the sonographic image has a round or oval cross-section, and it has a clear demarcation with the normal liver. In special cases, it may not have a clear boundary. Internal echo disordered and uneven strength may be divided into strong echo type, low-level echo, echoless type, and mixed type, without any signs of marked attenuation. Some may have an enhancement effort posterior to the tumor. After many follow-up examinations the volume of the tumor and characteristic of the sonographic image will have no changes. But individual carvernous hemangioma may enlarge rapidly within this short duration. The Union Hospital affiliated to the Fujian Medical University has found a case of cavernous hemangioma of the liver with a diameter about 8 cm; the volume of tumor has increased nearly 3 times within 2 weeks. It is proven to be cavernous hemangioma by surgical exision. A typical case may be diagnosed by sonographic image, but most cases should be combined with clinical and other examinations, such as radionuclide indium 113 blood pool scanning, which is usually beneficial to the diagnosis. One should take precaution when using small needle puncture for cytological and histological examination, in particular the cavernous hemangioma located in the superficial position of the liver is contraindicated for biopsy examination by liver puncture. Deep-seated hemangioma is an indication of needle aspiration for cytological or histological examination (Fig. 4.48).

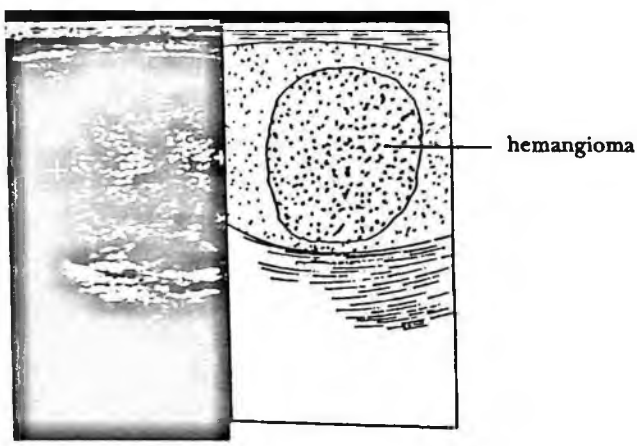

Fig. 4.48 Hemangioma of the liver.

(ii) Capillary hemangioma: the expression of the sonographic image is a strong echo type. It is present as a round or oval nodule inside the liver. Single or multiple, the demarcation with a normal liver tissue is rather clear. Owing to the small volume of the tumor, there is no sign of marked crushing with the intrahepatic structure (Fig. 4.49).

(iii) Adenoma of the liver: it is seldom seen. The expression of the sonographic image of the tumor is a low-level echo nodular mass. The boundary of the tumor is clear.

The echo has been reported to undergo multiple changes, it is complicated, the volume is rather big and irregular, and it is not easily differentiated from a malignant tumor. It should be combined with clinical analysis, and if necessary, histological examination must be applied through liver puncture.

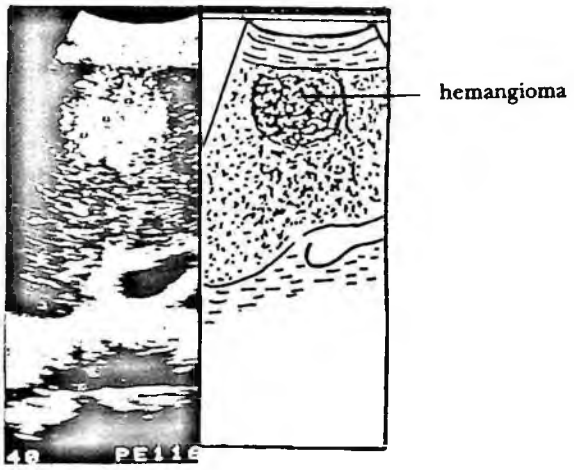

Fig. 4.49 Capillars hemangioma of the liver.

(c) Clinical examination of ultrasonic imaging diagnosis

Ultrasonic imaging can accurately display the size, position, morphology, internal macroscopic condition, and relations with the intrahepatic structure and extrahepatic viscera, in order to have a definite value in early diagnosis and differential diagnosis. According to the report at home and abroad, the accuracy of diagnosing a tumor of the liver by ultrasonic imaging can reach between 85%–95%. The diagnosis rate of a group of tumor by the author is 92.5% (75/81), while the rate of diagnosis by ultrasonic imaging at a university in Japan is 95% (38/40). In recent years, many comparative studies point out that ultrasonic imaging diagnosis for the tumor of the liver is better than X-ray and CT examination. Ultrasonic imaging diagnosis can display small focus with diameter around 1 cm outside the blind area. This discovery could become a great value in the early diagnosis of malignant tumors of the liver. Nowadays, it is extensively used to understand the condition of the liver before surgical excision of tumors of other viscera, and the probe is used during operation to detect focal location of the intrahepatic small tumor, and the condition of tumor embolus. Small needle puncture, as well as cytological and histological examination under the guide of ultrasound, do have a definite value. But owing to the physical factor of acoustics, the nature and manipulation of the instrument, and various pathological changes, it may also lead to many difficulties in diagnosis. In particular, there is still a definite difficulty in the differentiation between a primary malignant tumor, benign tumor, and secondary tumor. Therefore, it may be combined with carefully repeated clinical examinations in order to raise the accuracy (Table 4.4).

Table 4.4. Differentiating the Sonograms of the Malignant Tumor of the Liver and that of Hemangioma

Item	Hemangioma of the Liver	Primary Carcinoma of the Liver	Metastatic Carcinoma of the Liver
outline	usually round	irregular form	mostly round, or in small nodules
boundary	usually present	seldom present	echo is mostly absent
number of tumor masses	usually single	usually single	usually in multiples
internal echoes that are honeycomb like	often seen	seldom seen	usually none are seen
typical image	ethmoid sinus change	nodular mass	bull's eye sign
sound halo	seldom seen, not typical	often seen	seldom seen
light wheel	none	often seen	seldom seen
posterior side of the tumor	enhancement often occurs	enhancement often occurs	enhancement may occurs
compressibility	often marked	seldom seen	seldom seen
signs of oppression of the blood vessel	not marked, blood vessel may be found to enter the body of the tumor	marked	less marked
rate of growth	slow	fast	fast
metastasizing into the surrounding viscera	does not occur	may occur	may occur

4.4.2. Diffusive lesion of the Liver

4.4.2.1. *Cirrhosis of the Liver*

(a) Clinical and pathological

Cirrhosis of the liver may cause problems such as viral hepatitis, parasitic infection, nutritive metabolism, circulatory embarrassment, protract chronic obstruction of the biliary tract leading to extensive damage of the parenchyma of the liver, and eventually resulting in hepatic cell degenerative necrosis. This effect is followed with the appearance of hyperplasia of fibrous tissue and nodular regeneration of liver cells, leading to the appearance of nodular changes in the liver tissue, and its texture will finally become hard. According to the changes of the pathological morphology, cirrhosis of the liver is divided into the big nodular type, small nodular type, and mixed type. The nodule of the big nodular type is usually above 3 mm long; it may even reach several centimeters, it is usually formed after extensive necrosis of the liver cells; a majority of the small nodular type are less than 3 mm, and are mostly found in portal cirrhosis of the liver; the mixed type has both big and small nodules, mostly found in biliary cirrhosis of the liver. Early in the cirrhosis of the liver, the volume of the liver is mostly enlarged. At later stages, it will contract, and is usually accompanied by changes in the portal hypertension, and ascites.

(b) Expression of the sonographic image

(i) There is no special changes in the image of cirrhosis of the liver:

In the early stage, various degrees of enlargement of the liver can be seen. It is usually due to fatty degeneration and fibrous degeneration, causing the internal echo of parenchyma of the liver to become dense, and increase in strength and coarseness. In cirrhosis of the liver caused by schistomiasis, the volume of the left liver is bigger than the right one; while for cirrhosis of the liver due to chronic extravasation, or biliary cirrhosis, both the left and right lobes of the liver are generally enlarged, but in late stages the majority appear atrophied.

(ii) Capsular echo of the liver is mostly abnormal:

The contraction of a large amount of fibrous scars causes the surface of the liver to emboss unevenly, and appear wave-like or sawtooth-like (Fig. 4.50).

(iii) Disorder of the intrahepatic structure:

Disorder in the intrahepatic structure is caused by fibrosis. In serious cases, the biliary structure is destroyed, causing irregular twisting and making it difficult to identify. The cross-section of the hepatic vein is usually lost and not easily displayed. The trunk of the portal vein and its main branch usually become dilated and increase in coarseness. The splenic vein also increases in coarseness and becomes tortuous dilatated. Sometimes RBC form mass-like flashing image and may be related to the slow blood flow (Fig. 4.51).

(iv) Abnormal echo of the liver parenchyma:

At the early stage, one may find enhancement of echo, or a lack of change. At a later stage, there may be a marked increase in the coarseness of intrahepatic echo, presenting diffusive enhancement. The strength of the echo is non-homogeneous. Many reports consider that fibrous nodular changes during cirrhosis of the liver causes a large amount of sound energy to be absored and attenuated. Therefore, there is no clear display, at the posterior a patch of acoustic shadow appears. But

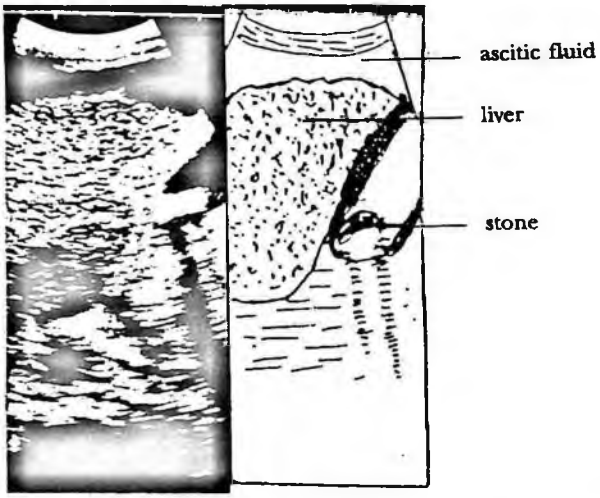

Fig. 4.50 Cirrhosis of the liver accompanied by the chololithiasis.

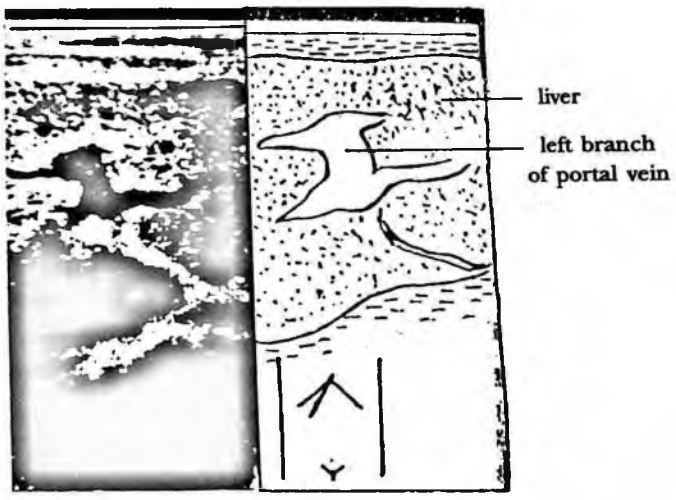

Fig. 4.51 Cirrhosis of the liver showing dilatation in the left branch of the portal vein.

the author, through observation at practical cases of cirrhosis, considers that the appearance of any serious attenuation is rare. The causes should be discussed further — these may be related to ascites effect, or the different sizes of the blood sinuses in the liver.

In schistosomiasis cirrhosis of liver, the intrahepatic echo is extremely non-homogeneous. It presents unevenly distributed cord-like band, or network-like structure, similar to the structure of a "map". Different sizes of the nodular echo may also be found in the liver affected by biliary cirrhosis, it is usually accompanied by the localized dilatation of the bile tract.

(v) Change in portal hypertension:

The cirrhosis of the liver is usually accompanied by portal hypertension, expression dilation of the portal venous system, splenomegaly, and formation of collateral circulation. Some commonly seen collateral circulation are the re-opening of the umbilical vein, tortuous dilatation of the left gastric vein and esophageal vein. The ultrasonic image easily displays the opening of the umbilical vein. Under normal conditions, the epiumbilical vein is closed after birth, and the round ligament is formed. Re-opening of the epiumbilical vein occurs during portal hypertension. From longitudinal section of the left liver on the upper abdomen, one may find it starting from the left branch of the portal vein at the umbilical region, running in the cord of the round ligament to the margin of the liver. The left gastric vein runs to the omentum minus along the lesser curvature of the stomach at the lower end of the esophagus, flowing into the hepatic end of the splenic vein, or the confluent part of the splenic vein and superior mesenteric vein. The normal left gastric vein is about 3 mm long. It may reach over 3 mm to beyond 5 mm during portal hypertension, presenting a string of beads. It may be examined by the longitudinal section along the abdominal aorta on the upper abdomen, or by cross-section at a high position. Also, it may be scanned from the left intercostal space. At the deep position, it may also be scanned from the left intercostal space. At the deep portion of the hilus of the spleen, one may find a markedly dilated gastric venous aneurysm, and it is often confluent with the left renal vein, this time it is usually accompanied by ascites.

In addition, the sonographic image varies due to the different causes of cirrhosis. Certain causes may be traced, such as cirrhosis of the liver due to ectravasation. It is usually accompanied by dilatation of the intrahepatic vein or the inferior vena cava, and may be traced to the obstructed portion of the hepatic vein or the inferior vena cava, respectively. It may also have a cardiac lesion, such as cardiac failure, pericardial effusion or cardiomyopathy. Biliary cirrhosis can usually be traced from a biliary tract lesion. Ultrasonic diagnosis of the cirrhosis of the liver

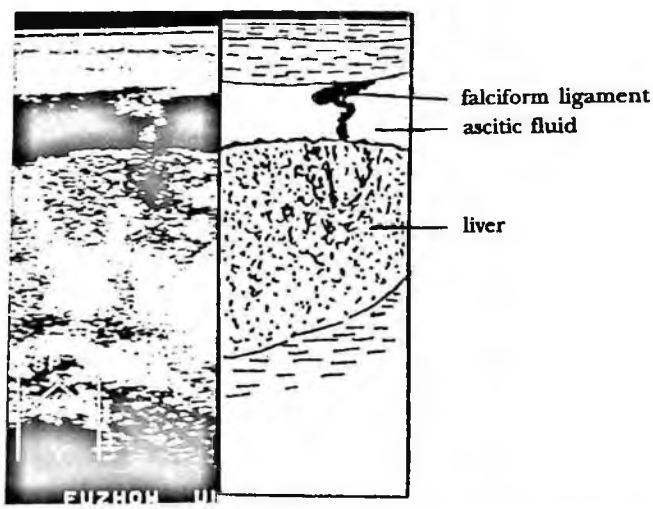

Fig. 4.52 Falciform ligament at ascites in the cirrhosis of the liver.

depends mainly on the morphology of the liver, outline of the margin, internal nodular change, and the accompanied sign. Variation of the ultrasonic image is rather special during its mid and later stages without any difficulty in diagnosis. But at the early stage, the cirrhosis of the liver and the expression of the ultrasonic image are not typical and should be differentiated from the following diseases: diffusive type of liver carcinoma, fatty liver, congenital fibrosis of the liver, and normal liver with ascites (Fig. 4.52).

4.4.2.2. *Fatty Liver*

(a) Clinic and pathology

Fatty liver is due to infiltration of lipid into the liver cell. The result is a marked increase in the lipid content in the liver. Its pathological change is generally an enlargement of the liver, obtuse margin, and tough texture. In serious cases, content of fat in the cell of the liver may reach more than 2/3, which is diffusively distributed with medium or big fatty cyst. Some of them contain about 50% of fat, and have various degrees of fatty liver. Fatty liver is divided into diffusive fatty liver and localize fatty liver.

(b) Expression of the sonographic image

Because the liver cell is infiltrated with lipid, this causes the intrahepatic medium to become non-homogeneous, and the interface becomes quite complicated. Therefore, an echo at the anterior 1/3 of the liver has a different degree of enhancement, presenting diffusive, dense, minute echogenic dots echoes. 2/3 of the posterior echo gradually decreases with the depth of the liver tissue. The liver is diffusively enlarged, the biliary tract echo inside the liver is markedly decreased. In general, ultrasonic image diagnosis is not difficult but some cases of fatty liver show no diffusive changes, and are only limited in certain lobe or segment. The ultrasonic image presents a patch-like enhancement of the echo area, usually having a marked demarcation with normal liver tissues. Sometimes, it may be mistaken for a space-occupying lesion in the liver, but with careful observation there is no sign of oppression surrounding the biliary tract. If

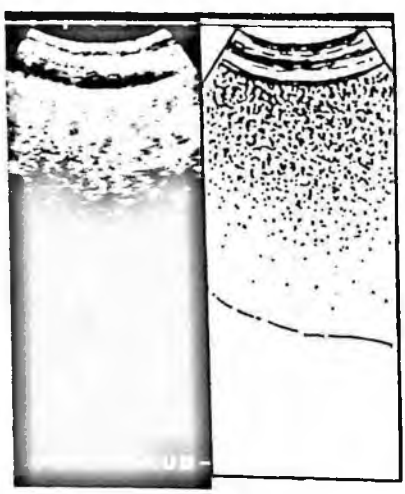

Fig. 4.53 Typical fatty liver.

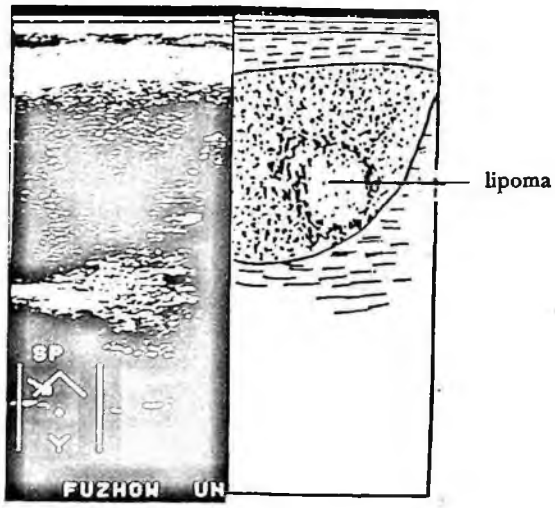

Fig. 4.54 Lipoma in the liver.

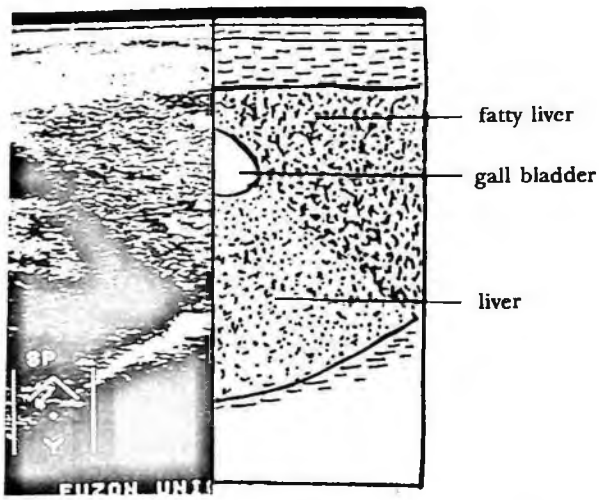

Fig. 4.55 Fatty liver at the left half of the liver.

necessary, it should be combined with other data in order to undergo diagnosis. The author has mistaken a case of intrahepatic localized fatty liver for liver tumor. It was only proven to be fatty liver after pathological examination after surgery (Figs. 4.53–4.55).

4.4.2.3. *Extravasation of the Liver*

(a) Clinical and pathological

The extravasation of the liver is one of the unknown cause to the enlargment of the liver. It is commonly and clinically seen. The main causes of the disease are obstruction of the hepatic vein to the inferior vena cava, chronic right cardiac insufficiency,

pericardial effusion, and particularly constrictive pericarditis and the dilatation type of cardiomyopathy. This can cause embarrassment of reflow to the inferior vena cava, leading to an increase in the pressure of the inferior vena cava, dilatation of hepatic vein, and extravasation and enlargement of liver in the long run. Thus, it may induce hyperplasia of fibrous tissues, finally resulting in the cirrhosis of the liver.

(b) Expression of the sonographic image

The expression of the sonographic image of the extravasation of the liver is rather typical. By generalizing the enlargement of the liver, the intrahepatic echo is extremely homogeneous and the strength of the echo is deviated to a low level. It marks the dilatation of the hepatic vein and it is clear that the dilatation of the inferior vena cava may be accompanied by splenomegaly or ascites. If the course is protracted, the intrahepatic echo will increase in coarseness and enhancement. Usually, the cause of extravasation can be traced to right cardiac failure or pericarditis (Fig. 4.56).

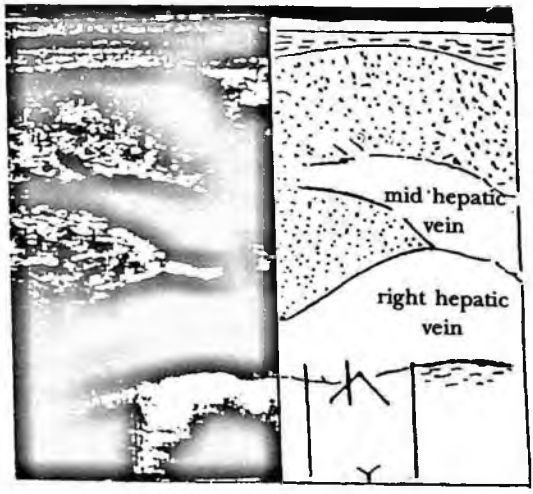

Fig. 4.56 Marked dilatation of the hepatic vein in extravasation of the liver.

4.4.2.4. *Tuberculosis of the Liver*

Tuberculosis of the liver is rarely seen in the city, but it may be discovered in certain districts. A tuberculosis focus is usually present in the lung or other organ by blood transmission, resulting in tuberculosis of the liver. The sonographic image is not typical. During the acute stage, it is similar to the changes for a case of hepatitis. A solitary focus usually presents a change of low-level echo. If it develops into a caseous necrosis change, an echoless silent area in hyperechogenic mass, or a light patch, may be discovered. This time it is easily mixed up with a liver tumor or liver abscess. It should be combined with clinical and other examination data for a comprehensive diagnosis.

4.4.2.5. *Schistosomiasis of the Liver*

There is no special changes at the early stage of liver schistomiasis, but at a later stage it usually developes into cirrhosis. Due to the fibrosis of the vein surrounding the hilus of the

liver, the intervention with pseudo small-lobe formed by the regeneration of hepatic cells, it will result in the complication of intrahepatic interface. The sonographic image shows a network-like change (as in a map), the intrahepatic biliary tract also displays an unclear, or deformed, stenosis and becomes coarse or unevenly fine. A majority of the patients also suffer from portal hypertension and splenomegaly.

4.4.2.6. *Diffusive Enlargement of the Liver*

Aside from the above-mentioned extravasation of the liver, the early stage of liver cirrhosis will also induce a diffusive enlargement of the liver. Certain hematopathy, such as chronic granulocytic leukemia and generalized infectious diseases, can also cause enlargement of the liver.

There is no specificity in the sonographic image of the hepatitis. It may appear to be a concentration of echogenic dots, and an enhancement of the echo. The liver is mostly diffusively enlarged in the acute stage. The thickening and roughness of the gall bladder wall is often seen. Cloudy echoes may be detected inside the gall bladder — similar to the change of the sonographic image of the inflammation of the gall bladder. Chronic hepatic appears to show non-homogeneous echogenic dots in the liver, or a patchy mass echo. It is usually accompanied by various degree of enlargement of the spleen. Due to hematopathy, the liver usually enlarges. The echo of the liver is mostly homogeneous, or presenting a change in the weak echo. Generalized infectious diseases such as septicemia, the liver is diffusively enlarged. Echo may be an enhancement type or a weaken type, and it is usually accompanied by the enlargement of the spleen or/and both kidneys. The sonographic image cannot be accurately used for the etioligical diagnosis for diffusive enlargement of the liver due to the above-mentioned causes. It should be combined with clinical and related examination data for a comprehensive analysis, but the ultrasonic image does play an important role in the understanding of the size and morphology of the liver. It is also valuable in excluding the enlargement of the liver due to space-occupying lesions, and understanding the volume of the liver during the course of transformation. During examination of the infectious hepatitis patient, effective isolated measures should be taken to prevent cross-infection, such as using thin layer of film to cap the probe, or using other special instrument.

4.4.3. Perihepatic Abscess and Sub-diaphragmatic Abscess

From the abdominal anatomy, the sub-diaphragmatic area includes the anterior hepatic space, the posterior hepatic space, and the inferior hepatic space. An abscess located outside the capsule of the liver is called a perihepatic abscess. Actually, the sub-diaphragmatic abscess is a kind of perihepatic abscess. Its position is high and deep, and found underneath the diaphragm. The sonographic image may detect no echo or a low-level echo in the above-mentioned space. The echo may be regular or irregular. The sonolucence is quite good. Its posterior appears to have a "enhancement effect". Sometime, it may be found with strong echogenic dots echo flashing, or many times of star tail reflection, which mostly indicates the gaseous motion of aerobatic bacteria.

A marked perihepatic abscess is usually accompanied by the elevation of the diaphragm, and limitation of the diaphragm's motion. An abscess in the inferior hepatic region may

cause an upward displacement at the right lobe of the liver, causing a change of the normal position of the right kidney and gall bladder.

The sonographic image can be used to diagnose the perihepatic accumulation of fluid, but it must be further combined with clinical data to make certain of the presence of empyema. Sometimes, it should differentiate itself from the right hydrothorax, the ascites and the abscess in the margin of the liver (Fig. 4.57).

It is important, when using ultrasound, to search for the cause of pyrexia of unknown origin, or post-surgical pyrexia. Both the left and right sub-diaphragmatic regions should be examined and the posterior aspect of the lower chest should also be scanned to exclude an associated pleural effusion.

Fig. 4.57 Right sub-diaphragmatic abscess.

Chapter 5

Ultrasonographic Diagnosis of Diseases of the Bile Duct

Lin Liwu

The gall bladder is an ideal organ for ultrasonographic examination. By observing its anatomical structure, the anterior superior region is the parenchyma of the liver. The fundus of the bladder is very close to the physical surface. Therefore, no matter from which acoustic or anatomical angle, ultrasonographic examination of gall bladder has excellent conditions. By means of ultrasonography, one can observe the tomographic image of the gall bladder at different sections. It can further objectively display the size and form of the gall bladder, the thickness of the gall bladder wall, and its relation with the surrounding tissues. Modern ultrasonography can not only comparatively display the stone, tumor, precipium, ascarid and all sorts of abnormality, but it also plays an important function in differential diagnosis of obstructive jaundice. In addition, under the guidance of ultrasound, per-cutaneous liver puncture for cholangiography, drainage, and cytological examination has its unique advantage, it is particularly important for drainage decompression during acute biliary tract disease. Therefore, ultrasonography becomes the first choice for the diagnosis and treatment of biliary tract diseases and acute diseases of the biliary tract at present.

5.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE BILE DUCT

5.1.1. Anatomy of the Gall Bladder

A normal gall bladder is located in the gall bladder fossa, which is found at the infero-anterior part at the right lobe of the liver, extending downward from the hilus to the margin of the liver. The gall bladder is somewhat like a pear, 5–8 cm in length, 3–4 cm in width, the anterior posterior diameter is also 3–4 cm, and its volume is about 40–60 ml. The gall bladder is divided into the fundus, the body and the neck. Its physical surface is positioned at the point crossing the right lateral margin of the right abdominal rectus at the upper

abdomen and hypocostal arch, or at the right ninth costal cartilage. The superior surface of the gall bladder is adherent to the liver by means of the loss of the connective tissue. The free fundus and the body of the gall bladder varies greatly. It is mostly connected with the right side of the transverse colon and the superior part of the duodenum. The neck of the gall bladder is as thick as a purse, and it expands forward. This is known as the gall bladder neck purse. The gall stone is usually stored in this purse. At the right hilus of the liver, the neck curves like an "S", firstly pointing towards the anterior upper then again turning to the inferior and connecting with the cystic duct.

The cystic duct is the extension of the neck of the gall bladder towards the left inferior posterior which is about 2–4 cm in length; mostly located at the right side of the common hepatic duct, and confluented with it to form the common bile duct, with about 80% presenting parallel convergence, 20% angular convergence and the mucous membrane of dutal wall is spiral in shape. Therefore, it often causes incarceration of the stone. The triangle enclosed by the cystic duct, common hepatic duct and the inferior surface of the liver is called the "gall bladder triangle". An abnormal cystic duct may turn around to the anterior right or left side of the common bile duct to join with the common hepatic duct.

Commonly seen abnormalities in the gall bladders are the double gall bladder, absence of a gall bladder, diverticulum of gall bladder and ectopic gall bladder, such as the gall bladder being located at the upper surface of the right or left lobe of the liver, or the gall bladder being transversely placed or placed in the sac of the omentum (Fig. 5.1).

The main functions of the gall bladder are the concentration, storation, and regulation of the bile juice needed for the body. A normal gall bladder will concentrate 5–10 times of gall juice for reserve use. Fat, yolk, and certain medicines may stimulate the duodenal mucous membrane to cause the constriction of the gall bladder to expel bile juice. It is commonly believed that the bile duct will bear the water pressure of 300 mm. In general, by means of concentrating the bile juice and altering the tension condition at the sphincter exit the of common bile duct, the storing and excreting of bile juice is regulated.

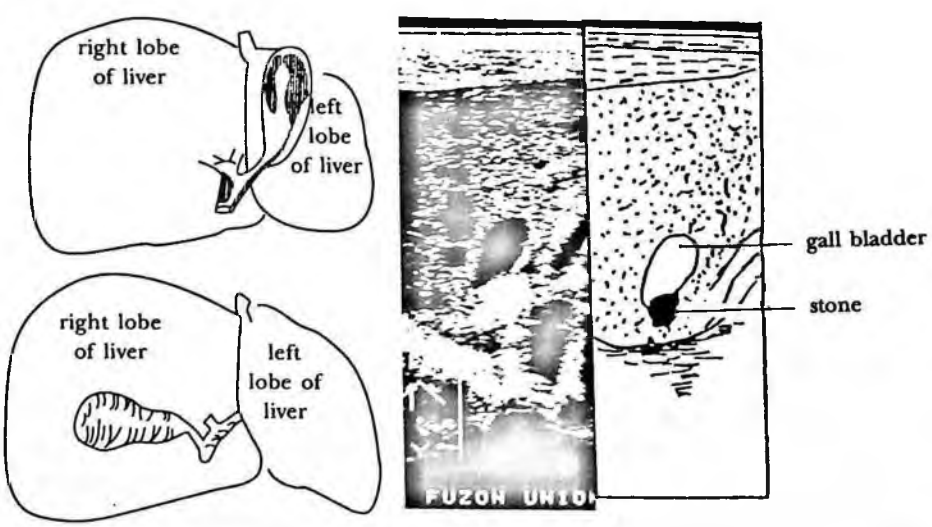

Fig. 5.1 Abnormality of the gall bladder. Left figure: sketch map illustrating the abnormality of the gall bladder. Middle figure and right figure: gall bladder with stone at the right lobe of the liver.

5.1.2. Anatomy of the Biliary Tract

The biliary tract system includes tracts from both the intra-hepatic biliary section and extra-hepatic biliary section. The intrahepatic biliary tract is formed by the micro-biliary tract, which is formed from the intrahepatic cellular cord (capillary biliary tract) injecting into the interlobular biliary tract in the liver, and gradually confluenting to form the hepatic segment and the hepatic lobular biliary tract. Then they are combined to form the big left and right hepatic ducts. At the hilus of the liver, the left and right hepatic ducts converge to form the common hepatic duct and descend downwards; the extrahepatic biliary tract is formed by the common hepatic duct, the gall bladder, the cystic duct and the common bile duct. The internal diameter of the intralobular biliary tract in the liver is 1.7–2.0 mm, not easily revealed by ultrasound. The left hepatic duct is rather long, averaging 1.5 cm; the right hepatic duct is rather short, averaging 0.8–1 cm. The internal diameters of the left and right hepatic duct are about 2 mm. The length of the common hepatic duct is about 3 cm, with an internal diameter of 3–4 mm. The common bile duct is the bile tract formed by the convergence of the common hepatic duct and the cystic duct. It runs along the right margin of the duodenal ligament downwards, passing posteriorly to the duodenum, and the common bile duct that grooves behind the head of pancreas is at 1/3 of the descending portion of duodenum to meet the pancreatic duct. After that, they run obliquely to the posterior lateral wall of the duodenum to share a common opening at the duodenal papilla at the site of convergence of the common bile duct. They expand in a shuttle manner, which is called the Verri's Ampulla. Normally, the common bile duct lies anterior to the portal vein to the right of the hepatic artery. Its total length is 7–8 cm, with an internal diameter of 5–8 mm. The common bile duct and pancreatic duct may either have a common orifice, or individual orifices. Sometimes, they may fill into the common bile duct and then fill into the intestinal tract (Fig. 5.2).

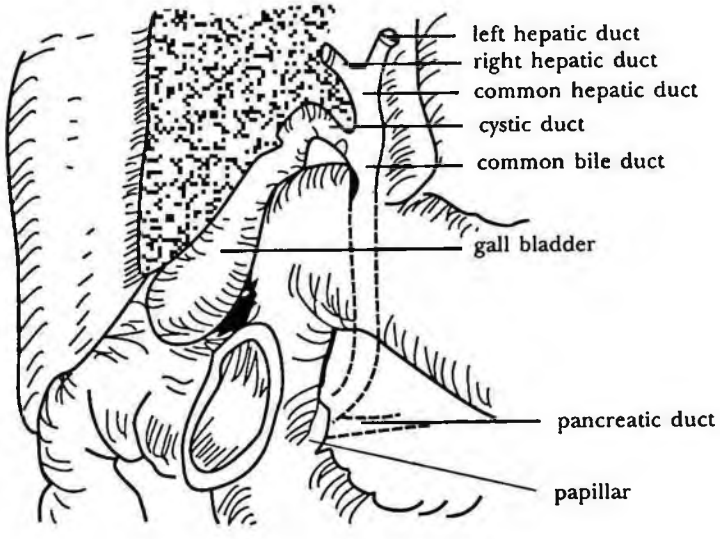

Fig. 5.2 Anatomy of the biliary tract.

5.2. ULTRASONIC METHOD OF EXAMINATION OF THE BILE DUCT

5.2.1. Preparation of the Patient and the Apparatus

Real time linear array sector is used with the arc mode ultrasonic apparatus and the probe frequency is set between 3.0–3.5 MHz. For a fat person, the frequency of the probe is set at 2.25 MHz, while for children the probe is set at 5.0 MHz. Readjust the sensitivity of the apparatus such as the ultrasonographic examination of the liver should clearly display the proper sensitivity of light band of echo of the gall bladder wall, the cleanliness of the gall bladder wall, the echoless area inside the gall bladder, and can clearly reveal the structures of portal vein and common bile duct at the hilus of the liver. Moreover, preparations should be made according to the different depths of the lesion, using a focus probe of either rear, medium, or far in depth.

To ensure the filling up of bile juice in the gall bladder and the biliary tract, and to minimize the interference of gastro-intestinal contents and gas, the following preparations should be made when conducting the B-mode ultrasound examination of the biliary tract:

(a) Before examination, fast for 12 hours or above and forbid fatty food for 24 hours;
(b) The ultrasonographic examination should be done prior to gastrointestinal and biliary tract roentgenography, or three days after a barium meal, and a re-examination should be done 2 days after the roentgenography;
(c) Stop using drugs such as atropine and eholagones which will affect the elimination of bile juice;
(d) Individuals suffering from severe abdominal distension may be re-examined after taking distension relief medicine or enema to raise the appearance of the gall bladder and the biliary tract;
(e) Patients suffering from obstructive jaundice can be examined when the abdomen is not empty.

5.2.2. Location and Method of Examination

5.2.2.1. *Examination in the Decubitus Position*

This is the fundamental ultrasonic method to examine the biliary tract, it will illustrate the prolapse wall of the gall bladder, and easily display the stone at the most prolapse part. By means of the longitudinal and transverse sections, this method allows the sound beam to be directly perpendicular to the wall of the gall bladder, and clearly display the stone at the inferior wall as well as the thickness of the gall bladder wall. It is usual to conduct the examination from the supine and left decubitus positions. The latter will expand the ultrasonic window when detecting the liver and gall bladder, at the same time it can also reduce the interference echo of the gastrointestinal gas and increase the appearance of the extrahepatic biliary tract. This method has a definite function in observing the stone at the neck of the gall bladder and in following the lesion in the middle and lower segments of the biliary tract. There are several approaches for the examination (Fig. 5.3):

(a) Oblique section below the right costal margin
Place the probe below the right costal margin in parallel, or in a definite angle, by sector

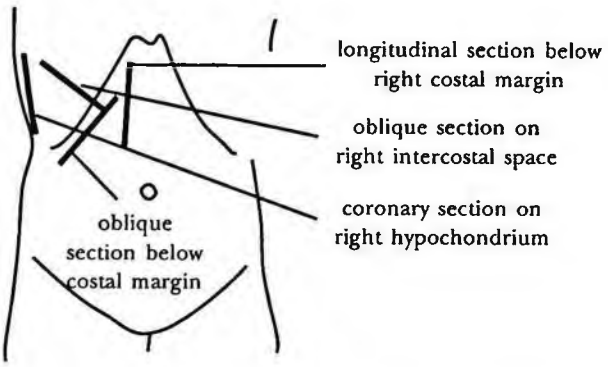

Fig. 5.3 Sketch map of the position of ultrasonographic examination of the biliary tract.

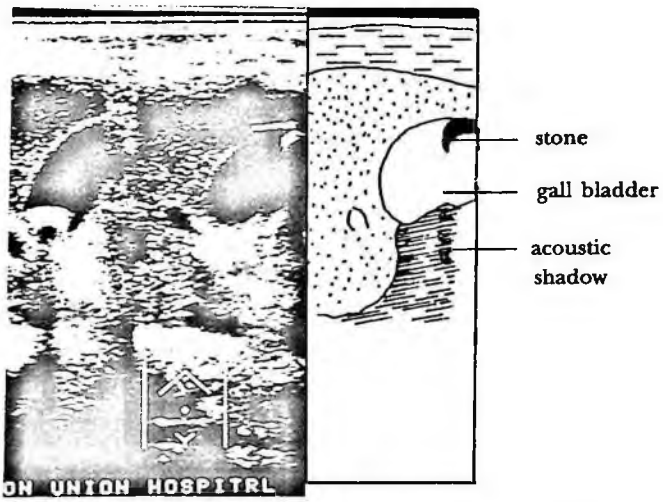

Fig. 5.4 Left figure: decubitus detection; Middle and right figures: chest-knee position examination, stone at the anterior wall of the gall bladder.

scanning. Ask the patient to take a deep breath so that the liver and the gall bladder will displace downwards and the movement of the gall bladder can be observed. Furthermore, it helps to understand whether there is adhesion between the gall bladder and the surrounding tissues. The oblique bisection below the costal margin is one of the main methods to obtain the length of the gall bladder (Fig. 5.4);

(b) Oblique bisection of the intercostal space
Place the probe on the right intercostal space, usually at the 5th–8th intercostal space to help display the gall bladder stone or atrophy of the gall bladder. At the same time it can display the portal vein, the common bile duct and the right kidney;

(c) Longitudinal section of the gall bladder
Place the probe below the costal margin at the right mid-clavicular line so that it will display the long axis of the gall bladder. This method will also give a better display of the stone in the body and fundus of the gall bladder, and at the same time it can bisect

the longitudinal section of the common bile duct to examine the stone at the lower segment of the common bile duct;

(d) Longitudinal section of the right hypochondriac region
This method enables the entire view of the gall bladder to be observed. Place the probe on the right hypochondrium at the anterior or the mid-axillary line to display the gall bladder through the liver. Because of the interference by the acoustic shadow of the rib, a clear entire view of the sonogram is often not obtainable.

5.2.2.2. *Examination by the Upright or Sitting Position*

For the purpose of examining the pathological changes at the fundus of the gall bladder or for further observing the movement of the stone or identifying the precipitating layers of the muddy stone, the upright or sitting position should be adopted. It is considered an important method of ultrasonic examination of the gall bladder. While examining in the decubitus position, a small stone inside the gall bladder may remain at the neck of the gall bladder. The sonogram cannot easily identify it because the small stone at the neck of the gall bladder maybe mixed up with the reflecting echo shadow of the spiral valve. At upright position, due to the action of gravity, the stone will mostly be located at the fundus of the gall bladder. In addition, an examination in the upright position also helps to differentiate the stone in the cavity of the gall bladder from the gas-filled intestine.

5.2.2.3. *Examination by the Chest-Knee Position*

When there is difficulty in examining the movement of the stone by the decubitus or the upright position, it is possible to use this method to examine the movement of the gall bladder stone. The patient assumes the chest-knee position. The probe is then placed on the anterior abdominal wall of the gall bladder region for scanning. The sonogram will display the stone at the anterior wall of the gall bladder, and its acoustic shadow, which is posteriorly perpendicular, causing the posterior wall of the gall bladder to be disconnected.

5.2.2.4. *Rotating and Sector Sweeping Methods*

By means of rotating and sector-sweeping, the gall bladder will be fully displayed and the volume of the gall bladder will be illustrated sufficiently. Spiral examination is especially helpful to examine a folded gall bladder.

5.2.2.5. *Examination by Increasing the Pressure of the Probe*

By increasing the pressure of the probe at the gall bladder region, the probe will be closer to the structure of the gall bladder, hence lessening the interference of the gas inside the intestine. At the same time, if the increase of the pressure causes any pain this method will help to diagnose cholecystitis.

5.3. SONOGRAM OF A NORMAL GALL BLADDER AND BILIARY TRACT

5.3.1. Gall Bladder

Under normal conditions, the morphology of the sonogram varies with different bisections; the longitudinal section of the gall bladder is pear, round-, oval- or eggplant-shaped. It usually varies with the individual. The outline of a normal gall bladder is clear, and the curve of the gall bladder wall is rather smooth and clear-cut. Inside the cavity of the gall bladder is an echo-free silent area. The posterior wall line is bright and the rear of the posterior wall appears to enhance the reflecting effect. Both sides of the gall bladder also have a boundary shadow.

At the oblique section on the right intercostal space, the gall bladder is usually in a long, oval shape. In this bisection, it is rather easy to display the longest diameter of the gall bladder. The fundus of the gall bladder is usually located at the upper right of the sonogram, extending the lower left dissection to the hilus of the liver, which is called the neck of the gall bladder. At the neck there may usually be a folded display at the two walls; after moving the angle of the probe, the two walls sometimes fuse, forming two round or eggplant-like silent areas. A gourd-shaped gall bladder may display two folds.

5.3.2. Biliary Tract

The examination of the common bile duct usually involves the structure of the gall bladder, the trunk of the portal vein, or the head of the pancreas for acoustic anatomy. Ultrasonography usually divides the extrahepatic biliary tract into the upper and the lower segments: the upper segment sends out from the hilus of the liver and is accompanied by the portal vein, the lower segment is accompanied by the inferior vena cava extending to the lateral side at the back of the pancreas head. The display of the upper segment of the extrahepatic biliary tract by ultrasonography is mainly done by oblique scanning along the right intercostal space. At this point of time, the bile duct lies on the internal inferior region of the gall bladder, the anterior of the portal vein, and parallel to the portal vein to form a double channel structure with the portal vein. Its diameter is less than 1/3 of the respective portal vein. In a normal lower segment of the extrahepatic biliary tract, because of the interference caused by the flatulence inside the gastrointestinal tract, it is quite difficult to be displayed. Methods such as probe scanning with increased pressure and filling of water to the gastric antrum and duodenum can effectively increase its appearance. When cutting the transverse section of the head of the pancreas, the lateral side at the back of the pancreas head and the round cross section of the lower segment of the common bile duct in front of the inferior vena cava can be revealed. When the lower segment of the common bile duct is blocked, the common bile dilates, and both the upper and lower segments of the extrahepatic bile duct can be easily displayed. Under the xyphoid, longitudinal scanning is the usual way to display the lower segment of the extrahepatic bile duct. When the long axis of the probe is parallel to the common bile duct, the common bile duct will display a segment of the small bile duct structure, which is about several centimeters long in front of the internal lobe portal vein. At the cross-section, the extrahepatic bile duct, the hepatic artery, and the portal vein will be displayed at the same time as three circular channeling structures,

like the right and left ears of Mickey Mouse, representing the extrahepatic bile duct and hepatic artery, respectively. The contemporary ultrasonographic apparatus already clearly displays the left and right biliary tracts. Its trademark is the left and right branches of the portal vein. Anterior to the left and right branches of the portal vein are the left and right hepatic ducts, its internal diameter is usually less than 2 mm. If there is dilation inside the intrahepatic bile duct, it will combine with the postal vein to present a channel sign in parallel.

5.3.3. The Normal Status of the Gall Bladder and the Biliary Tract

The size of the gall bladder varies significantly. It is absolutely related to eating and drinking, the individual bodies, and the direction of ultrasonographic examination.

In 1983, the National Ultrasonography Diagnosis Academic Conference formulated a proposal of determining the normal status of the gall bladder: its approximate length is 5.4 ± 0.9 cm, its width is 2.2 ± 0.4 cm. After 349 examinations of normal gall bladders, which were done by the Union Hospital (affiliated to the Fujian Medical University), the results are as follows: the length of the gall bladder is 5.7 ± 0.87 cm, whereas the diameter from the front to the rear is 2.51 ± 0.41 cm. In general, its length is less than 3 cm.

The internal calibre of the bile duct varies among individuals: that of a normal adult in general, is not over 6 mm, the bile duct of an old man or a person after cholecystectomy may dilate, but in general the internal calibre is not longer than 8 mm.

5.4. DIAGNOSIS OF THE BILIARY TRACT ANALYZED WITH ULTRASONOGRAPHY

5.4.1. Method of Ultrasonographic Analytical Diagnosis for the Gall Bladder

5.4.1.1. *The Size and the Morphology of the Gall Bladder*

A normal gall bladder has a long oval shape. Its wall is delicately fine and smooth. In case there is a pathological change in the gall bladder, it will show constriction, expansion or no revealing changes in the gall bladder etc., in the sonogram.

(a) Constriction of the gall bladder

It refers to the patient to be examined who has fasted for more than 12 hours. If the bladder is still constricted, it is mostly due to a chronic inflammation or a scar, causing atrophy of the gall bladder; the presence of stone in the gall bladder and multiple polyp, leading to the dysfunction of the gall bladder; or a fully-filled stone causing great constriction of the gall bladder. We can carefully detect to see a crescent-typed liquifying silent area at the strong echo focus where the bile juice is when the location of detection is at the strong echo focus and its posterior acoustic shadow of the gall bladder region. In grave acute hepatitis, constriction of the gall bladder often occurs in a patient at the later stages of the liver carcinoma or with serious damage in the liver. But when analyzing the constriction of the gall bladder, the examiner must note whether the patient ate before the examination, or whether there is a biliary cyst at the gall

bladder fossa after cholecystectomy, because sometimes they resemble a constricted gall bladder (Fig. 5.5).

(b) Expansion of the gall bladder

The most common cause of gall bladder expansion is the blocking of the common bile duct. At this time, one can find the intrahepatic dilation of the biliary tract, the gall bladder stone in the common bile duct, ascarid, inflammation or tumor etc. in the sonogram simultaneously. The next common one is chronic cholecystitis accompanied with chololithiasis, causing obstruction in the cystic duct, or pressure exerted on the cystic duct by the tumor at the hilus of the liver. At this point of time the gall bladder is filled up and there is a marked increase in its length and width. The expansion of the gall bladder should be distinguished from enlargement of the gall bladder due to prolong fasting. The gall bladder of the latter will shrink immediately after a meal (Fig. 5.6).

(c) No revealing of the gall bladder

No revealing or unclear revealing of the gall bladder may be observed in the following cases:

(i) Abnormal positioning of the gall bladder, such as congenital ectopic gall bladder or the gall bladder being incarcerated into the foramen of omentum;

(ii) Congenital absence of the gall bladder is comparatively less seen, however, it is often found in infants;

(iii) The gall bladder has been removed. The previous cases, in general are usually quite accurate, but some cases are still uncertain and require careful examination. (A patient after having a gall bladder excision usually has a compensator enlargement);

(iv) An unclear revealing of the atrophy of the gall bladder, particularly for overweight individuals and those who have a marked flatulence in their abdomen, for whom the revealing is much more difficult. At this point of time, the examiner must pay particular attention to the right lobe of the liver and the right kidney. Starting

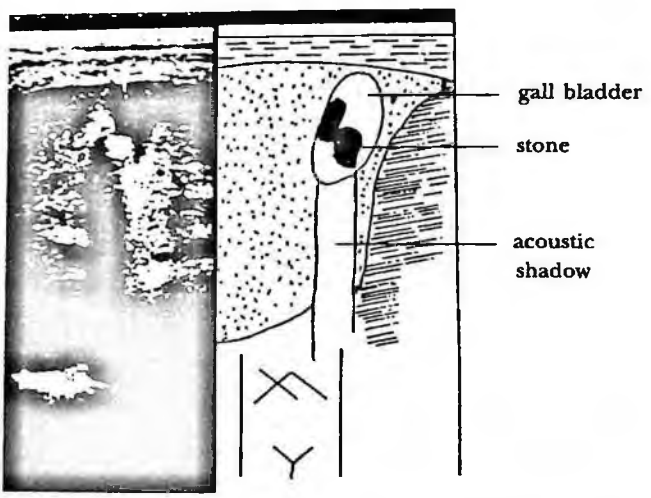

Fig. 5.5 Gall bladder constriction accompanied by stone.

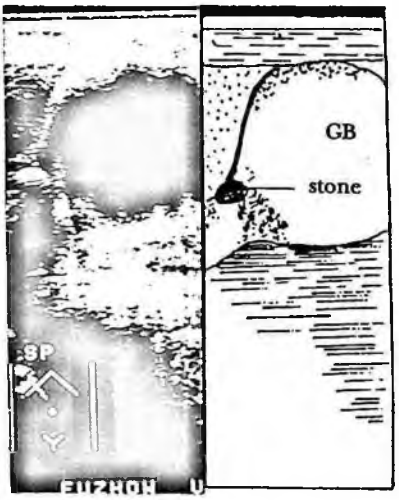

Fig. 5.6 Gall bladder stone accompanied by gall bladder expansion.

from the gall bladder and the hilus of the liver, we may transversely cut a section of the right lobe of the liver from the top to bottom. After revealing the right kidney, move the probe laterally towards an upper right direction, and after revealing the gall bladder, rotate the probe 90° to display the long oval- or shuttle-shaped gall bladder. Sometimes, the constriction of the gall bladder, especially chronic inflammation or the presence of double layers of gall bladder wall in the gall bladder after a meal is easily mistaken as pylorus. At this moment, the patient may drink some water for differentiation;

(v) The gall bladder is filled with gall-stone, its outline is not easily revealed. At the crescent acoustic shadow or long strip acoustic shadow in the gall bladder region and at the upper part of the acoustic shadow, one can often find a crescent-shaped echoless silent area;

(vi) The concentration of bile, causing echoes inside the gall bladder, which are similar to the echoes from the liver, causes the gall bladder to be displayed unclearly. Commonly observed symptoms are chronic obstructive jaundice, grave hepatitis, disease of the biliary tract itself and others which can cause insufficient intake of food and lead to high concentration of the bile. The sonogram presents some even, tiny echogenic dots of medium echo, similar to the echo of the parencyma of the liver. After careful identification, an echo band of the gall bladder wall can be seen;

(vii) When the gall bladder cavity is filled with a gall bladder tumor, when it is attacked by the metastatic tumor, or when the tumor of the liver presses upon the gall bladder, the gall bladder will not be filled up and will not be displayed clearly (Figs. 5.7–5.9).

(d) Deformity of the gall bladder

Deformity of the gall bladder is usually detected during chronic cholecystitis, inflammation around the gall bladder, and adhesion of the gall bladder with the surrounding tissues, which causes stretching, and result in a triangular or polygonal ultrasonograph of the gall bladder. At this point of time, the examiner should analyze

and observe the multiple sections. Usually, the thickness of the gall bladder wall, partial irregular increase in thickness, or the association with cholecystolithiasis is observed.

5.4.1.2. *Internal Echo of the Gall bladder*

A normal gall bladder has an echoless, dark area. The internal echo of a pathologically changed gall bladder is quite abnormal. Commonly seen symptoms are the presence of stone, inflammation, muddy precipitum, ascarid, tumor, and flatulence presenting the following abnormal echoes:

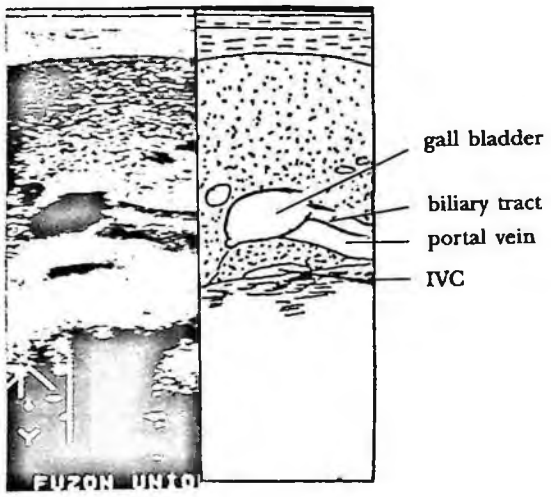

Fig. 5.7 Ectopic gall bladder (the gall bladder is situated in the right lobe of the liver).

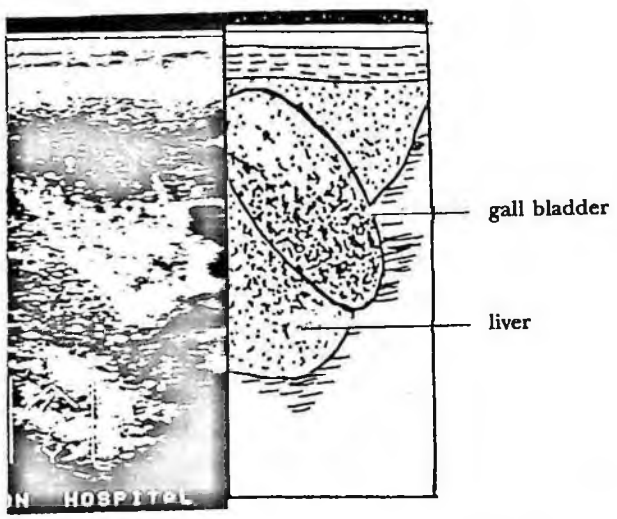

Fig. 5.8 Large amount of sediments in the gall bladder.

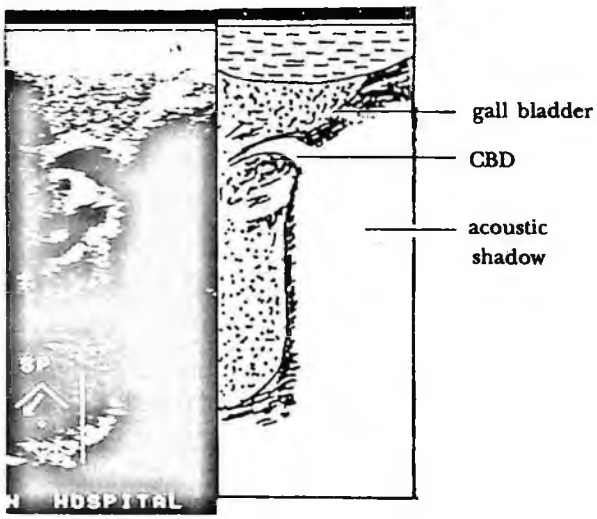

Fig. 5.9 Gall bladder constriction accompanied by stone.

(a) Moveable abnormal echo with acoustic shadows inside the gall bladder
It is seen in stone-forming and calcification. The forming of a gall stone may be divided into bilirubin, cholesterol, or mixed type, and they usually appear as a strong echo hyperechogenic mass. Their posterior are accompanied with an acoustic shadow, and they can move according to the change in their body positions. Some cholesterol gall stones or stones formed by ascarid can float inside the gall bladder and approach the upper wall of the gall bladder. Next, the space of the calcified stones contains gas and allows the stones to be movable. However, the examiner must pay attention to exclude any oral intake of radiographic medicine into the gall bladder, which causes the specific gravity of the bile to increase and the stones to float.

(b) Gaseous echo inside the gall bladder
Many causes, such as cholecystitis due to aerogenic bacilous infection and bile duct duodenal fistula, can lead to the accumulation of gas inside the gall bladder mostly at the anterior wall of the gall bladder. If the intrahepatic bile duct is accumulated with gas, a linear strip or tree- like strong echo can be observed in the liver, which can move along with the change in position or with respiration. Then it may have a "star tail" sign with multiple echoes, and is mostly seen after choledochendysis.

(c) Abnormal movable echo inside the gall bladder without the acoustic shadow
A strong echo is often seen in tiny stones, owing to the diffraction of sound beam or its inability to focus on the stones which cannot form the acoustic shadow. In low-level-echo cases, it is often seen in the muddy precipitum of bile, remains of ascarids, tumor, or blood clot. Sometimes, due to recent retrograde pancreato-cholangiography causing the sedimentation of radiography medicine, one may also observe a low-level mass inside the gall bladder.

(d) Abnormal, nonmovable echo of the gall bladder
This may be seen in the polypoid changes in the gall bladder, tumor, pussy material, blood clot and the prominence of folding membrane of the gall bladder wall. It should be examined from different directions and in the lateral decubitus or chest-knee

position in order to determine whether it is moving or not. Sometimes, it may be accompanied by cholecystolithiasis.

(e) Surface echo of the fluid inside the gall bladder
This is commonly seen during chronic obstruction of the bile duct, or in a patient who is undergoing long-term fasting, causing concentration of bile and muddy sediments inside the gall bladder. The latter purulent precipitating material in pyogenic cholecystitis, and hemorrhage in the bile duct can all show the fluid/fluid level echo (Fig. 5.10). That is, this plane will still be maintained on the horizontal surface when the patient is rotating his body. At this point of time, the examiner must differentiate the artifact induced by the thick effect of the sound beam.It is only needed to alter the direction of the probe, even though the image is changed or has disappeared. In addition, the image of the minute echogenic dots is fake, and does not form a straight line with the bile layers, the fluid/fluid level is not straight, but is a hazy curved line.

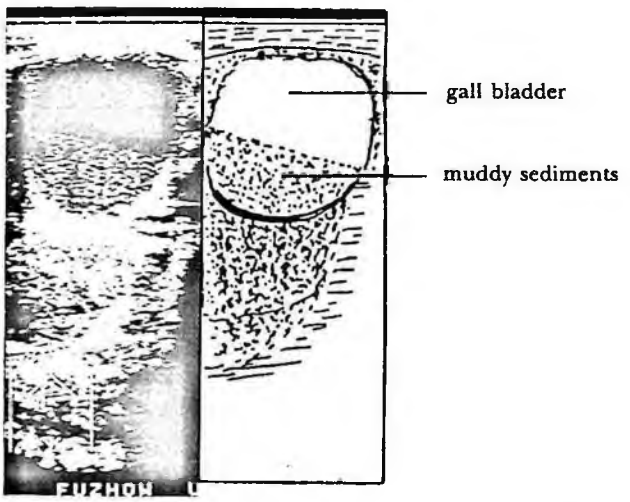

Fig. 5.10 Muddy sediments within the gall bladder form a fluid–fluid level.

5.4.1.3. *Echo of the Gall Bladder Wall*

The normal echo of the gall bladder wall is a smooth, linear, strong echo. The wall is about 2–3 mm thin. After eating, it will be as thick as two wall layers, reaching to 5–6 mm. An abnormal gall bladder wall can be seen in the following cases:

(a) Diffusive thickening of the gall bladder wall
Diffusive thickening of the gall bladder wall is seen from a contracted gall bladder after a meal, acute or chronic cholocystitis, acute hepatitis, cirrhosis of the liver with portal hypertension, heart diseases like conjestive heart failure, the reflowing obstruction of the gall bladder lymph and other serious liver diseases. For the contraction of the gall bladder after a meal, the cavity of the gall bladder may shrink and the wall of the gall bladder may show three layers in structure. The internal layer has the mucous

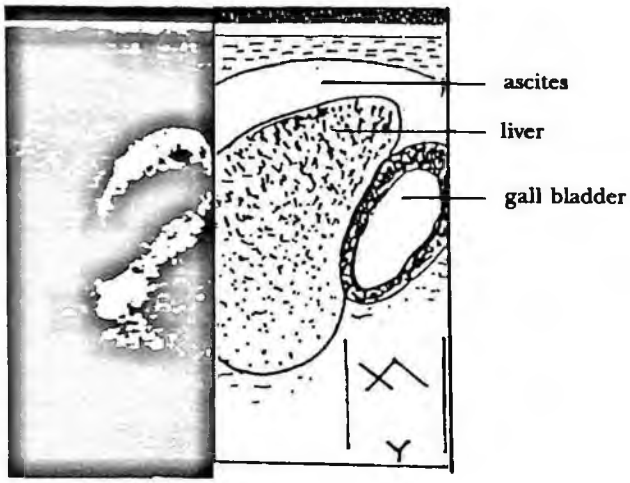

Fig. 5.11 Cirrhosis of the liver wih portal hypertension, the gall bladder wall thickens.

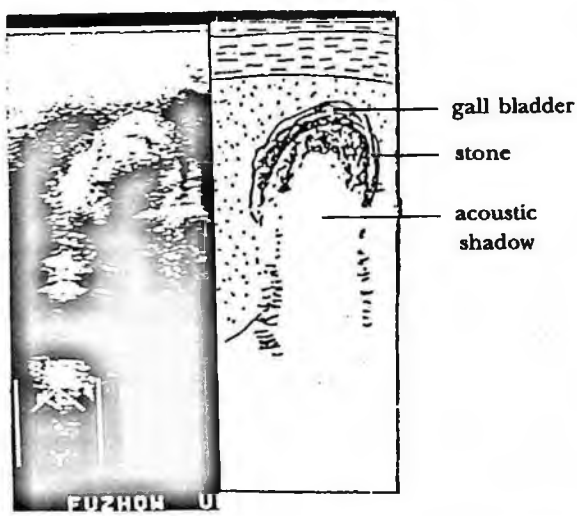

Fig. 5.12 Chronic cystitis, the gall bladder wall thickens.

membrane presenting a strong echo, the middle layer has the irregularly-contracted unstriated muscle presenting a low echo, and the outer layer is the capsule of the strong echo. After fasting for 12 hours, the thick gall bladder wall of the patient will soon become thin. Gall bladder walls with pathological changes will remain thick after fasting for 12 hours. Increase in the thickness of the gall bladder wall, caused by acute hepatitis and cirrhosis of the liver with portal hypertension, is related to the decrease in plasma albumin or reflow of the gall bladder vein in portal hypertension. It is usually accompanied by shrinkage of the gall bladder. The gall bladder will shrink and the echo of the bile becomes cloud-shaped. The thickening of the gall bladder wall due to acute cholecysttits is usually over 5 mm, and it mostly presents a three-layer construction. The

middle layer is a low-level echo due to inflammation or edema. The thickness of its wall is irregular, its sonolucence is poor, and is usually accompanied by stone, ascarids, cloudy sedimentation or flatulence in the gall bladder. The surrounding of the gall bladder will have an irregular silent area due to effusion (Figs. 5.11–5.12).

(b) Localized thickening of the gall bladder wall

This may be found in chronic cholecytitis, myoadenosis of the gall bladder, and in the tumors of the gall bladder. Chronic cystitis may cause irregular localized thickness in the gall bladder wall. It is often accompanied by enhancement of echo due to fibrosis or by gall bladder wall due to myoadenosis of the gall bladder. Myoadenosis may have a low-level echo gap. Even though that is a concentrated bile or small pus embolus, it may still have a strong echo focus. The tumor of the gall bladder usually includes the metastatic focus of the tumor nearby or at the hilus of the liver (Fig. 5.13).

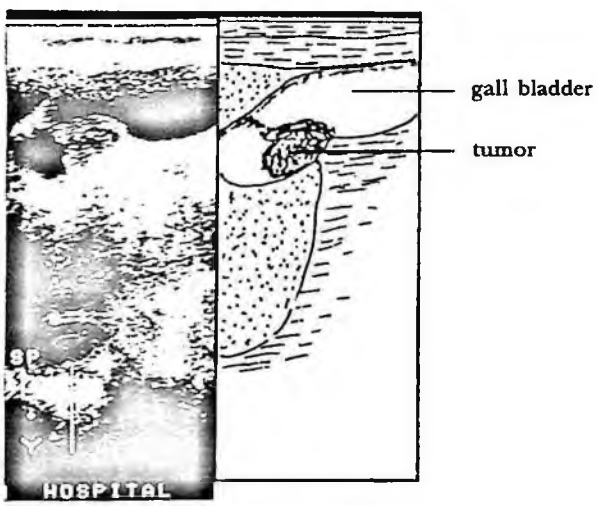

Fig. 5.13 Gall bladder tumor, localized thickening of the gall bladder wall.

5.4.1.4. *Abnormal Echo at the Gall Bladder Fossa*

In a normal gall bladder fossa, only the echo of the gall bladder can be found. During acute or gangrenous cholecystitis accompanied by abscess around the gall bladder or ascites, there will be effusion surrounding the gall bladder, or the tumor of the gall bladder relocates when metastasis of the gall bladder tumor or swelling of the lymph node at the hilus of the liver occurs, or the atrophied cholecystitis is accompanied with cholecystithiasis, causing an acoustic shadow to appear at the gall bladder fossa. At this point of time the gall bladder often does not appear. The echo of the gall stone often appears as a strong echogenic strip. When the body position is changed, there is a definite relation between the acoustic shadow and the liver. The upper part of the stone may have a crescent echo-free area. At this moment, it should be necessary to differentiate among the gas on the gall bladder wall, the flatulence in the intestine and calcification of the gall bladder wall (Fig. 5.14).

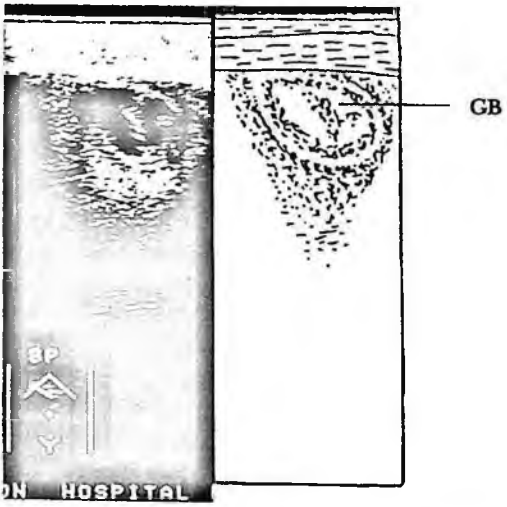

Fig. 5.14 Gangrenous cholecystitis.

5.4.2. Ultrasonic Method to Diagnose and Analyze the Bile Duct

5.4.2.1. *Dilatation of the Bile Duct*

The causes for dilation of the common bile duct and common hepatic duct are as follows:

(a) Stone in the bile duct
This is the most common cause of bile duct dilatation. At the distal end of the obstruction, there may be strong hyperechogenic masses accompanied by acoustic shadows, or there may be stones at the upper point of the obstruction. Sometimes, a stone is formed at the lower segment of the common bile duct or at the segment of the pancreas head, which usually displays the stone unclearly. At this point of time, the examiner may take the transverse section of the head of the pancreas for observation to see the strong echo and the acoustic shadow of the stone, but there is no dilated bile duct in the surrounding. At this moment, the examiner should differentiate the gas from other foreign bodies like surgical clips and the drainage tube (Fig. 5.15).

(b) Tumorous change inside the bile duct
The main causes are ascarids, tumor, muddy sedimentation, blood clot, etc. Ascarid often appears as a long strip, double tubular wall accompanied by a central low-level echo band. Sometimes, movable ascarid can be observed, but one must be cautious about the secondary short, tubular, false structural echo inside the bile duct. The appearance of muddy sediment inside the bile duct, presented as a low-level echo or medium solid echo, changes with the adjustments of the body position. At this point of time, pyogenic cholangitis must be considered as acompanying the sediments. The tumor in the bile duct will cause the bile duct to dilatate, such as polypoid carcinoma of the bile duct or carcinoma at the lower segment of the bile duct. But sometimes, dilatation of the bile duct is not obvious in carcinoma of the bile duct (Fig. 5.16).

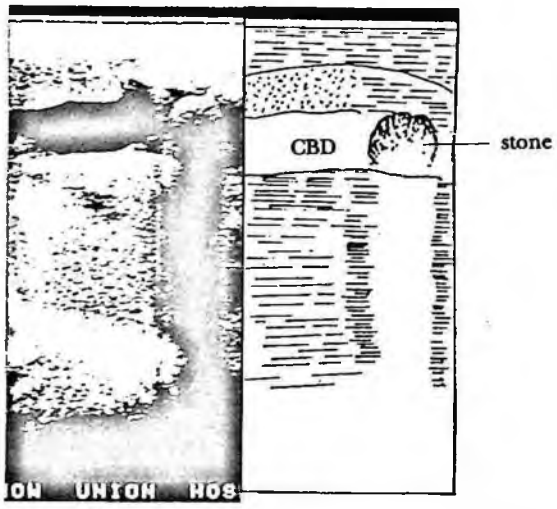

Fig. 5.15 Stone in the common bile duct, the common bile duct dilates.

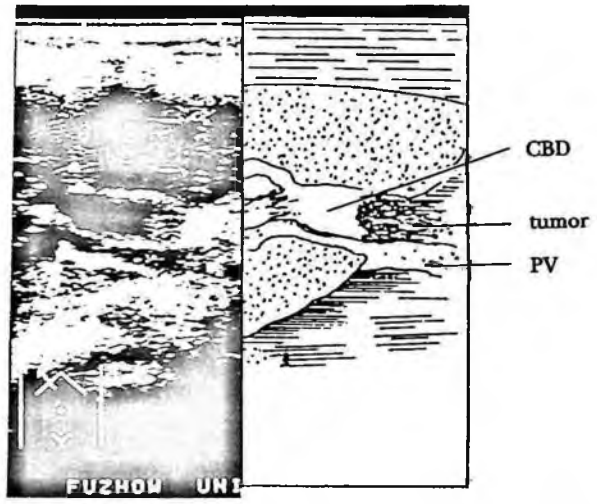

Fig. 5.16 Tumor in the common bile duct.

(c) Tumor in the surroundings of the common bile duct

This will directly cause an obstruction to the bile duct, or the obstruction may be due to the tumor exerting pressure on the duct. Examples are carcinoma at the head of the pancreas, carcinoma of the ampulla verter, or the extension of the carcinoma to the lymph node and the surrounding portal vein, all of which can cause obstruction to the bile duct and dilatation. Furthermore, liver carcinoma, pancreas tumor or the swelling of the lymph node surrounding abdominal aorta, congenital cyst of the common bile duct and cyst surrounding the bile duct can all press on the bile duct to cause obstruction (Fig. 5.17).

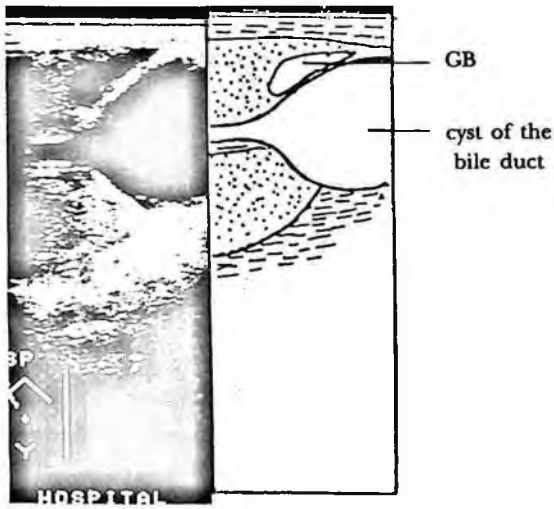

Fig. 5.17 Congenital cyst of the common bile duct.

(d) Stone in the cystic duct or tumor pressing on the common hepatic duct
Their effects on the common hepatic duct are dilatation of the part of bile duct above the obstruction (common hepatic duct and intrahepatic bile duct). The common bile duct does not dilatate but at the same time the gall bladder is markedly dilatated.

(e) An obstructed common hepatic duct, but with a normal calibre
It can be obscured in the case of the tumor embracing the common hepatic duct, the thickening of the gall bladder wall due to sclerotic cholangitis at the bile duct, or the formation of hidden gall stones, at the distal end of the bile duct. At this moment, the fatty-meal method can be used for the examination. If the calibre at the orifice of the bile duct is constricted after the fatty meal, it is normal; if the calibre of the bile does does not change or widen, the bile duct is obstructed.

(f) Dilatation of the extrahepatic bile duct without associating with dilatation of intrahepatic bile duct
When obstruction at the lower segment of the bile duct is not obvious, dilatation of the extrahepatic bile duct is found to occur. The intrahepatic bile duct dilatates unclearly or does not dilatate at all.

5.4.2.2. *Inability to Examine the Common Bile Duct*

The inability to display the common bile duct or common hepatic duct can be seen when there are muddy sediments in the bile duct, inflammatory materials inside the inflammatory bile duct, gases filled inside the bile duct or when there is stenosis of the bile duct after an operation. Muddy-like gall stones in the bile duct is usually accompanied by cholecystollithiasis and dilatation of the intrahepatic bile duct, which is accompanied with gall stones. The gas inside the common bile duct is usually found after the operation of the bile duct, and is usually accompanied by gas in the intrahepatic bile duct, and presented as a movable linear echo. Sometimes, the examiner may find the intestine filled with gas at the hilus of the liver. The stenosis of the bile duct is mostly seen in post-cholangiotomy. Due to

the contraction of the scar or thickening of the gall bladder wall due to inflammation, a marked narrowing of the tubular lumen result.

5.4.2.3. *Dilatation of the Intrahepatic Bile Duct*

In accordance with the degree and position, dilatation of the intrahepatic bile duct can be divided into the margin and hilus of the liver, mostly accompanied by the running of the portal vein and tubular structure of its branch. The dilatated intrahepatic bile duct is like the branch of a tree, twisted, or shows small square-like echoless silent areas. It may also be divided into local focal dilatation and diffusive dilatation.

(a) Local focal dilatation
It may be caused by sclerotic cholangitis, obstruction by a tumor, compression of a stone on the lower segment of the bile duct or other obstruction causes. If the left hepatic duct is obstructed, it will cause dilatation at the bile duct in the left liver. If the right hepatic duct is constructed, it will cause dilatation at the bile duct of the right liver. At this point of time the gall bladder and the common bile duct will not dilate (Fig. 5.18).

(b) Diffusion dilatation
Obstruction of the common bile duct or the common hepatic duct, tumor on the junction of the left and right hepatic duct, swelling of the lymph node at the hilus of the liver, and pressure due to metastatic focus can lead to diffusive dilatation of the bile ducts in the left and right liver without dilatation of the gall bladder or the common bile duct.

5.4.2.4. *Thickening of the Bile Duct Wall*

It is mostly observed after repeated infection at the bile duct, sclerotic cholangitis or carcinoma of the bile duct, accompanied by various degrees of dilatitis or carcinoma of the

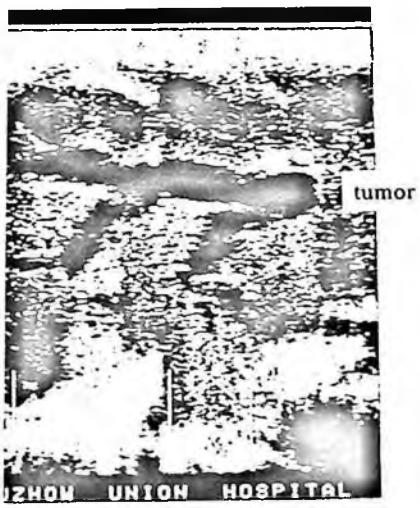

Fig. 5.18 Tumor in the right hepatic duct causes dilatation of the bile duct of the right lobe of the liver.

bile duct. Inside the bile duct there may be abnormal echoes due to the presence of muddy sediments or stones, and these are mostly accompanied with sonographic changes of chronic cholecystitis and cholecystolithiasis. At this point of time, examiners should differentiate this from fibrotic changes surrounding the portal vein due to the cirrhosis of the liver or schistosomiasis, which lead to the thickening of the bile duct wall. The latter's thickening of the bile duct wall is without cholangitis, dilatation of bile duct, and echo due to muddy sediments and stones. In addition, signs of portal hypertension may be displayed, such as dilatation of the portal vein, splenomegaly and ascties. The liver may also show signs of liver cirrhosis or schistosomomiasis in the sonogram.

When doing ultrasonographic analytical diagnosis for the bile duct, the examiners should pay attention to the structures surrounding the bile duct, such as the right kidney, the liver, pancreas, and the inferior vena cava, as to whether these structures are normal besides the above-mentioned signs of the gall bladder and the bile duct. Furthermore, knowing whether it is effusion in the thoracic cavity, motility of the right diaphragm, or the swelling of lymph node around the abdominal aorta is also helpful in diagnosing bile duct diseases.

5.5. ULTRASONOGRAPHIC DIAGNOSIS OF COMMON DISEASES OF THE BILE DUCT

5.5.1. Cholelithiasis (Bile Duct)

5.5.1.1. *Cholelithiasis (Gall Bladder)*

(a) Clinical and pathology

Cholecystolithiasis is usually accompanied by cholecystitis. The cholesterol, bilirubin, bile salt and calcium salt coagulated into gall stones under the action of repeated infection, sludging up of bile juice and embarrassment to the metabolism of cholesterol. They are divided into three categories according to the different components:

(i) Cholesterol stone: its main component is cholesterol, and it usually appears as a single big stone, which may reach to 3–5 cm. It is mostly seen in the gall bladder. It is either round or oval with a smooth surface. Its section is in a radiated shape, and is seldom observed under the X-ray.

(ii) Bilirubin stone: its main component is calcium bilirubinate. It may contain small amounts of cholesterol. It is muddy- or sandy-like and is mostly seen in the bile duct, and may be revealed under X-ray.

(iii) Mixed type: it is mostly formed by bilirubin, bile salt and cholesterol. It is usually a polyhedron with either a smooth or rough surface. It may reach several hundreds in number. It is often seen in the gall bladder and may be revealed by X-ray.

(b) Sonographic illustration

Due to the different composition of stones, many factors can cause the formation of stones, especially cholecystolithiasis and cholecystitis, which are usually the cause and effect, and both have a mutual effect. Therefore, the sonographic expression of the location, morphology, size of the gall stones and the gall bladder's condition vary greatly, and is classified into typical or non-typical sonographic changes.

(i) Typical sonographic changes of cholecystolithiasis. Inside the gall bladder there is a strong hyperechogenic mass or echogenic dots, which may be proved by a multiple-section examination. Posterior to the hyperechogenic mass and echogenic dots, there is a perpendicular acoustic shadow. When the body position is changed, the hyperechogenic mass and echogenic dots may be moved (Fig. 5.19–5.20).

(ii) Non-typical sonographic changes of cholecystolithiasis: the atrophy of the gall bladder and an unclear outline are mostly due to a stone-filled gall bladder. At this point of time, the examiner sees only a strong echo band accompanied by a perpendicular acoustic shadow at its posterior. This is the illustration of chronic atrophied cholecystitis accompanied by cholecystolithiasis (Fig. 5.21).

The stone at the neck of the gall bladder may cause obstruction to the cystic duct and dilatation of the gall bladder. The hyperechogenic mass of the stone is not clearly displayed,

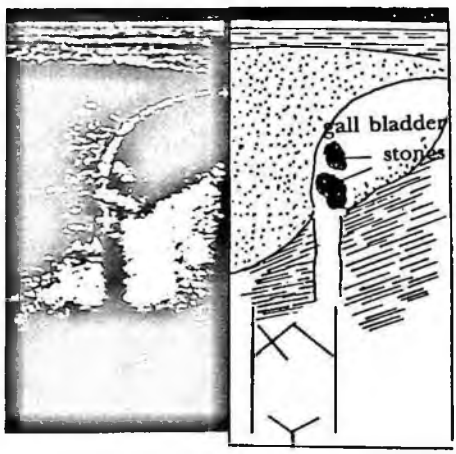

Fig. 5.19 Typical cholecystolithiasis. (gall bladder stone)

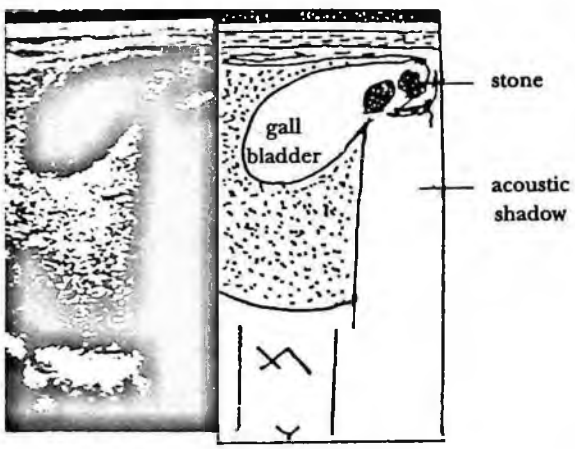

Fig. 5.20 Cholecystolithiasis.

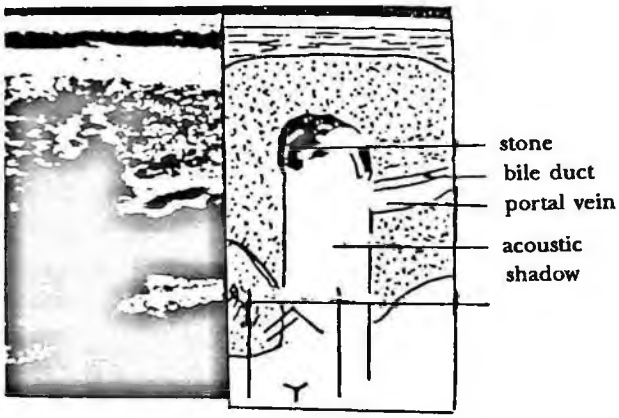

Fig. 5.21 Atrophied gall bladder accompanied by stone.

and is not easily differentiated from the wall echo at the neck of the gall bladder. Sometimes, the acoustic shadow at its posterior also cannot be differentiated from the refracted acoustic shadow at the neck of the gall bladder. At this moment, one may use examinations with multiple positions, such as the decubitus or chest-knee position, which is easier to expose the shifting stone. Another way is to examine by means of fatty meal to further determine whether there is a blockage at the neck. This is very helpful for the diagnosis of stones incarcerated at the orifice of the neck.

A strong echo with a crescent hyperechogenic mass accompanied by an acoustic shadow at its posterior can be observed inside the wall of the gall bladder which has stones attached to the wall. When the body position is changed, the hyperechogenic mass does not move. It is usually due to the stone at the fundus or stones attached to the obviously inflammed gall bladder wall, and are often multiples in number. At this point of time, it is not easy to differentiate from the polyp in the gall bladder or pussy embulus at the wall. The acoustic shadow behind the stone is very helpful for diagnosis.

When there is a muddy stone, the outline of the gall bladder is still clear. The margin at one side becomes coarse and thick. Its posterior wall can be found to have tiny echogenic dots. Acoustic shadows can also be found at its rear. The echogenic dots move with the change in body position and usually becomes a plane shape. In general, stones with great specific gravity will deposit at the lower part of the posterior wall, stones with light specific gravity will float or suspend in the bile juice. Sandy granule stones move quickly with the change in body position. Muddy stones are rather clumsy and the sticky mud even heaps into a ball. The echo is even quite similar to a tumor mass protruding into the gall bladder cavity (Fig. 5.22). Sometimes, it is not easily moved with a change in body position; the body must move in great amplitudes or detection by upright or chest-knee position must be used. By making use of acoustic shadows and motility, they can be differentiated from the redundant growth of the gall bladder (Fig. 5.23).

The rate of detection of cholecystolithiasis by ultrasonography is rather high. The accuracy of the diagnosis may be as high as 80 to 96%. According to the data from Tokyo University in Japan (1981), the accuracy is 96%, which is higher than the rate of diagnosis by CT (75%). Domestic reports also give an accuracy of around 95%. From 1982–1983, based on the comparison between 110 cases of ultrasonography image detection and the results of

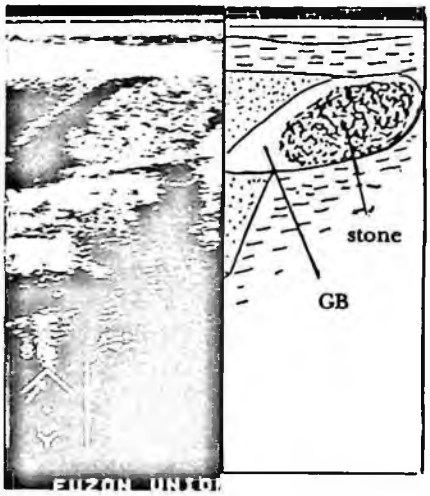

Fig. 5.22 Muddy stone in the gall bladder heaped up as a ball.

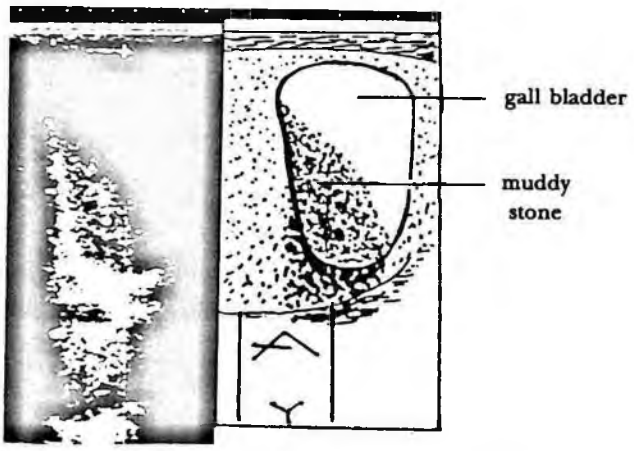

Fig. 5.23 Muddy stone in the gall bladder.

cholecystoctomy, Union Hospital affiliated to Fujian Medical University, had a diagnosis accuracy that reached 96.4%. Recently, the author took 132 cases (1987) and compared them with the results of the operation, and the rate of conformity was 97.8%.

Nevertheless, ultrasonographic diagnosis on cholecystolithiasis still contains false negative and false positive. It is a big problem that the clinical field is concerned with. The detection technique and identification ability should be further increased. The common causes of false positive are as follows:

(i) Gas in the gastrointestinal tract: the gas in the duodenum particularly, is usually at the neck of the gall bladder and forms a hyperechogenic mass and acoustic shadow. After careful observation, one may find the light cluster very active and unstable. The

hyperechogenic mass disappears with a change in the probe's directions. The position of the gall bladder changes with the change in body position while the light cluster will not move with the gall bladder. At the same time, the acoustic shadow of the gas is turbid and unclear. Drinking water to fill the stomach will sometimes cause the disappearance of the gas, or a change in its position;

(ii) Inflammatory fragment of blood clot: the sonogram shows hyperechogenic masses or echogenic dots, which are similar to stones or muddy stones, but there are no acoustic shadows at their back. They will not move with any change in the body positions, but will be in a floating form (Fig. 5.24);

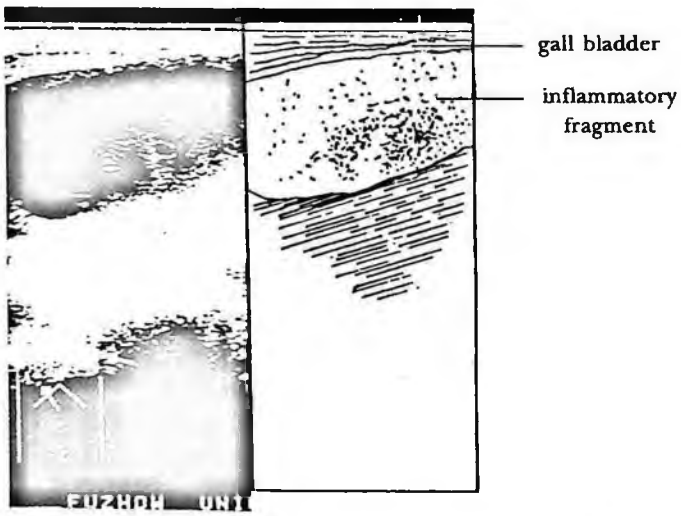

Fig. 5.24 Inflammatory fragment inside the gall bladder in pyogenic cholecystitis.

(iii) Bending at the neck of the gall bladder: the acoustic shadow may be due to refraction. Proceed with different body positions to search for the undetected gall stone;
(iv) Outgrowth on the wall of the gall bladder;
(v) Bending folds of the gall bladder cap at the fundus of the gall bladder;
(vi) Connective tissue scars around the gall bladder or substantial tumorous tissue around the gall bladder. The echo of hyperechogenic mass stays fixed when the body position is changed, and there are no typical acoustic shadow at its back;
(vii) The artifact induced by sound beam thickness effect will be mistaken for muddy stones, it disappears when the direction is changed.

The causes of false negative of cholecystolithiasis are as follows:

(i) The stone is too small or the stone is at the neck of the gall bladder;
(ii) The echo of the stone is low, without obvious acoustic shadow at its back, such as the cholesterol stone;
(iii) Atrophy of the gall bladder which is accompanied by stones;

(iv) High position of the gall bladder, flatulence in the abdominal cavity, or being too fat can cause changes in the position of the gall bladder;
(v) Too big a gall bladder, giving rise to incomplete and misdiagnosed detections (Fig. 5.25);

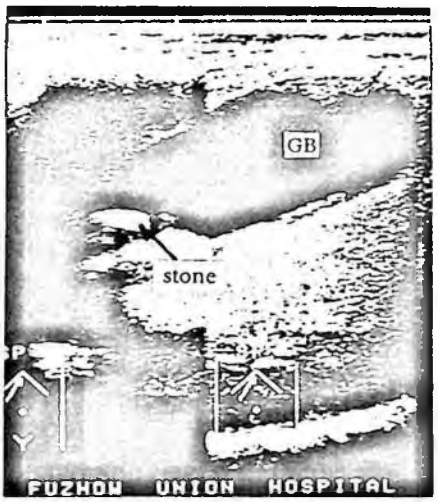

Fig. 5.25 Congenital giant gall bladder with stone.

(vi) Examining after a meal, hence giving a poor display of the gall bladder;
(vii) The gastrointestinal tract is covered by large amount of gas which causes artifact due to neglected vision;
(viii) Improper examination technique, hence inducing misdiagnosis.

In order to increase the accuracy of the diagnosis of cholecystolithiasis with ultrasonographic imaging, the following points should be noted during detection:

(i) Be well prepared before the detection, such as fasting, avoid taking radiography medicine and pancreato cholangiography;
(ii) Conduct the examination with multiple body positions and multiple directions to let the sound beam face perpendicularly to the stone;
(iii) Apply different gains and compare repeatly;
(iv) Avoid the interference from the flatulence at the gastrointestinal tract.

5.5.1.2. *Bile Duct and Intrahepatic Stone*

(a) Clinical and pathology
Cholelithiasis is a common disease in China. It is closely related to parasitic infection, chronic cholangitis, and abnormal metabolism. Cholelithiasis are mostly bilirubin or the stone may be mixed with cholesterol. Due to the narrowness of the bile duct, it is unlike the gall bladder which has a good acoustic translucent shadow. Therefore, the

rate of display is much lower than that of cholecystolithiasis, particularly the muddy bilirubin stone, which often fills the whole segment of the bile duct and causes ultrasound display to be more difficult. Because the obstruction of the bile duct often causes dilatations of the upper segment of the bile duct, one must pay attention to the echoes at the distal end and the acoustic shadows at the back. Proper body positions and applying proper directions for detection may increase the positive rate. According to literature reports, the accuracy rate of diagnosing choledocholithiasis is 60–80%. However, the recent report showed the rate to be about 90%. The author had estimated (approximately in 1986) the rate of conformity compared with surgical results out of 126 cases to be 92%.

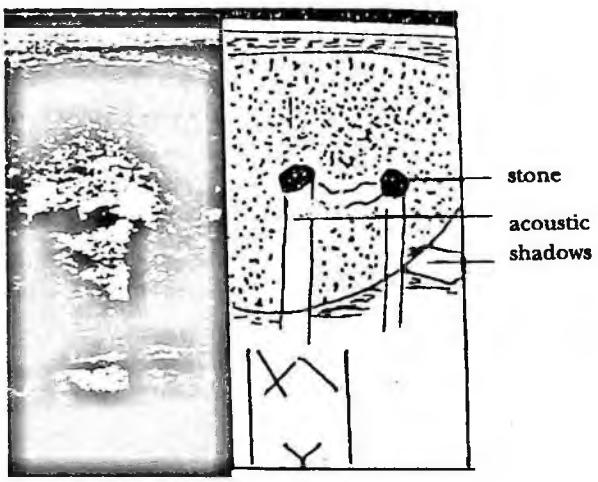

Fig. 5.26 Intrahepatic cholangiolithiasis.

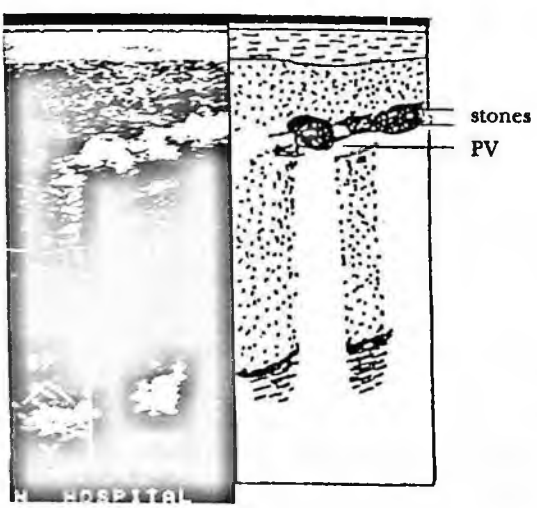

Fig. 5.27 Intrahepatic cholangiolithiasis.

(b) Sonographic expression

(i) Stone in the intrahepatic bile duct is called hepatolith in short. It is mostly seen at the anterior segment of the left or right lobe. Because there is a marked difference in the acoustic impedance between the parenchyma of the liver and the stone, the rate of display of the intrahepatic stone becomes high. At the cross-section of the liver, a marked enhancement of light clusters, echogenic dots and light band can be detected. At its back there is a corresponding perpendicular acoustic shadow and it runs with the corresponding branch or portal vein. It may also appear in certain segments of the liver or develop diffusively. Sometimes, it may cause localized dilatation of the bile duct at the upper segment of the stone, presenting a branch-like, echo-free, silent area band. The fully-filled type of intrahepatic stone appears like a branch with a strong echo light band. The cross-section is a round light cluster or echogenic dots. This should be differentiated from the flatulence in the bile duct inside the liver. The latter is unstable or is like a flickering, strand-like light band. At its back, one can find the star tail sign with many echoes. At the same time it should be differentiated from the intrahepatic ligament and the round ligament. The round ligament of the liver is in the left lobe. Looking at the cross-section, the round or irregular light cluster or the echogenic dots are located at the anterior to the sagital portion of the portal vein. From the longitudinal section, a cord-like light band is located between the left branch of the portal vein and the umbilical region below the liver (Figs. 5.26 and 5.27).

(ii) Stone in the extrahepatic bile duct. The extrahepatic bile duct starts from the hilus of the liver and ends at the Vater's ampulla. Therefore, the lower segment of the bile duct is easily covered by the reflected gas in the gastrointestinal tract, which is difficult to display. But due to obstruction by stones, the bile duct is often dilatated. A rather big stone in the bile duct appears as a long oval light cluster. The direction of its long axis is identical with the direction of the bile duct. A small narrow bile juice silent area is available to embrace the hyperechogenic mass of stones, causing the bile juice silent area and hyperechogenic mass of stones to form a cup-mouth shape. Behind the hyperechogenic mass, there is a perpendicular acoustic shadow (Figs. 5.28 and 5.29).

The stone in the common bile duct is usually a bilirubin stone, present in the form of small granules or in a muddy form. Therefore, when the internal calibre of the bile duct is small or when the diameter of the stone is less than 3 mm, it is not easily displayed. At this point of time, both the longitudinal section below the xyphoid and the transverse section on the head of the pancreas at the upper abdomen can prove the existence of the stone. Sometimes by using a fatty meal test, the chances of detecting the stone at the lower segment of bile duct will increase.

The conformity rate of ultrasonographic diagnosis and the rate of operation for choledocolithiasis is lower than that for cholecystolithiasis. The reason for this is not only due to their positions at the common bile duct, but it is also influenced by the following factors:

(i) The time of ultrasonographic examination is not identical with the time of operation, hence there is a possibility of the stone itself being eliminated;

(ii) Relaxation of the sphincter at the ampulla by anesthesia during operation, the stone will be expelled into the duodenum by the effect of pressure inside the bile;
(iii) The small stone cannot be examined by ultrasound or operation;
(iv) The artifact of gas is misinterpreted as stone by ultrasound;
(v) Stone in the bile duct is always movable, and it will continuously pass down from the small bile duct and the hepatic duct into the common bile duct, hence it is not like the gall stone which is rather stable.

The left and right hepatic duct stone may be identified by using the left and right branches of the portal vein as landmarks. The intrahepatic bile duct will dilate at the side of

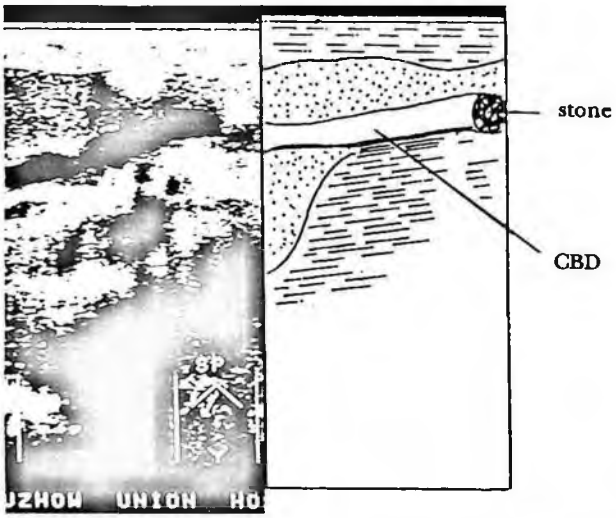

Fig. 5.28 Stone at the lower segment of the common bile duct.

Fig. 5.29 Giant stone at the common bile duct.

the liver where the stone often occurs. The non-typical stone should be differentiated from the calcification and the fibrosis ones.

5.5.2. Cholecystitis and Cholangitis

5.5.2.1. *Cholecystitis*

Cholecystitis is mostly due to the obstruction of the cystic duct or/and the common bile duct causing the stagnation of the bile juice or/and bacterial infection. Ascris is an important cause of congestion of the mucous membrane, edema, and exudation, which cause thickening at the gall bladder wall. When obstructed, the bile juice stagnates and can cause the gall bladder to swell. When the serous membrane is congested, its surface will have exudated purulent fibrin attached. Due to the lack of blood circulation, it can cause extensive hemorrhage and necrosis of the gall bladder wall, leading to perforation and biliary peritonitis. In chronic inflammation, the mucous membrane of the gall bladder is usually destroyed and becomes flattened or coarse and uneven due to hyperplasia of the connective tissues. Fibrosis of the gall bladder wall, hyperplasia or hypertrophy, are usually adherent to the surroundings and have lost their normal morphology. Prolong and incomplete obstruction will cause the gall bladder to enlarge markedly. If aerogenic bacilous infection occurs, which is accompanied by flatulence of the gall bladder or the bile duct, the venous circulation of one may find edema at the gall bladder wall. These pathological changes all have corresponding sonographic changes.

Sonographic expression of acute cholecystitis:

(a) Marked enlargement of the gall bladder, especially the increase of the width can cause the gall bladder to appear oval or round in shape, and the outline to become hazy;
(b) The wall of the gall bladder thickens markedly, forming a double layer structure. Its middle point is the lower level echo area, which is due to the congestion of the mucous

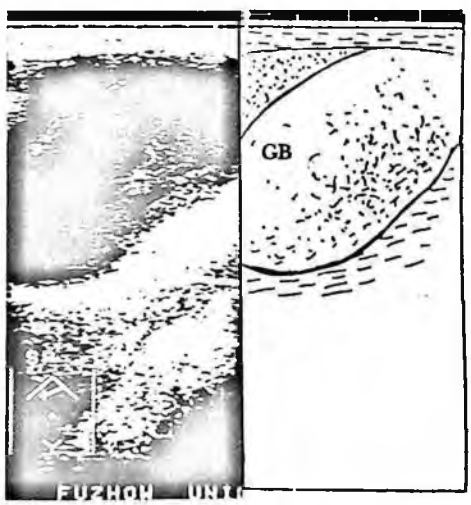

Fig. 5.30 Acute cholecysttiyis, giant gall bladder.

membrane of the gall bladder and the edema of the subserous membrane. Its thickness may be more than 5 mm;

(c) Inside the gall bladder there may be cloudy echo or echo bands of muddy precipitum;
(d) Stones or ascaris are usually found inside the gall bladder. At the same time they are accompanied by dilatation of the bile duct, stone, ascarids, and other sonographic changes;
(e) In case of perforation of the gall bladder, the localized effusion of its surrounding may change;
(f) In case of aerogenic bacteria infection, gas echoes may be found in the cavity of the gall bladder (Fig. 5.30).

Sonographic changes of chronic cholecystitis:

(a) In mild cases, thickening of the gall bladder wall occurs. There is an increase in the intensity of the echo, but not much change in its morphology and size;
(b) In serious cases, more significant thickening of the gall bladder wall occurs. It is often more than 5 mm thick, the echo becomes clear bright, and its edge is much rougher. In addition, the thickness of the wall is uneven;
(c) The enlargement of the gall bladder can be caused by obstruction of the cystic duct, or mostly through diffusion of the gall bladder. At this point of time the inflammatory reaction becomes unclear. After the original bile juice is absorbed by the mucous membrane, it is replaced by colorless mucin secreted from the mucomembranous gland, which is called white bile juice. At this time, the gall bladder is markedly enlarged. Because the tension is not high and it appears in a long shape with low positioning, the gall bladder wall may not increase in thickness. Thus, the stone inside is often misdiagnosed;
(d) Chronic cholecytitis due to severe fibrosis can cause atrophy of the gall bladder and is accompanied by large amounts of stones;
(e) The normal bend of the gall bladder neck is often lost, the body shape of the gall bladder becomes stiff, or it loses its normal form and appears as a triangle or polygonal shape, which is related with the surrounding adhesion;
(f) The majority of the chronic cholecystitis cases come together with cholecystolithiasis or ascaris;
(g) The contraction ability of the gall bladder becomes poor or disappear (Fig. 5.31).

Thickening of the gall bladder wall in chronic cholecystitis should be differentiated from carcinoma of the gall bladder, cirrhosis of the liver with portal hypertension, hypoglobulia or contraction after meal. All these causes should be combined with another sonographic features and clinical data in order to differentiate them.

5.5.2.2. *Perforation of the Gall Bladder*

Due to the all sorts of reasons which cause acute cholecystitis or acute attacks of chronic cholecystitis, the gall bladder wall is conjested with blood and edema, causing lack of the blood circulation of the gall bladder wall, hence extensive necrosis occurs. Because of the juice, the gall bladder swells and eventually perforate biliary peritonitis appears.

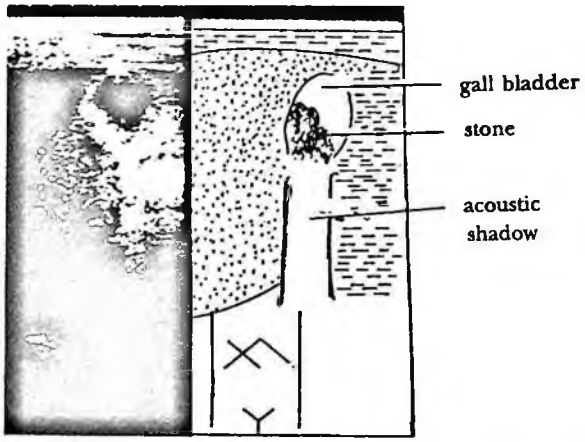

Fig. 5.31 Chronic cholecystitis accompanied by cholecystolithiasis.

Sonographic expression of the gall bladder perforation:

(a) This has the ultrasonographic image of acute or chronic cholecystitis;
(b) Often accompanied by ultrasonic images of ascaris or stone inside the gall bladder;
(c) One may find interruptions to the continuous line at the gall bladder wall and an irregular small silent band of low level echo being presented;
(d) Irregular liquified silent area may be found around the gall bladder or at the site of perforation. Gall bladder perforation, which has existed for a long period of time forms a low-level echo area often due to inflammatory adhesion with the surrounding (Fig. 5.32).

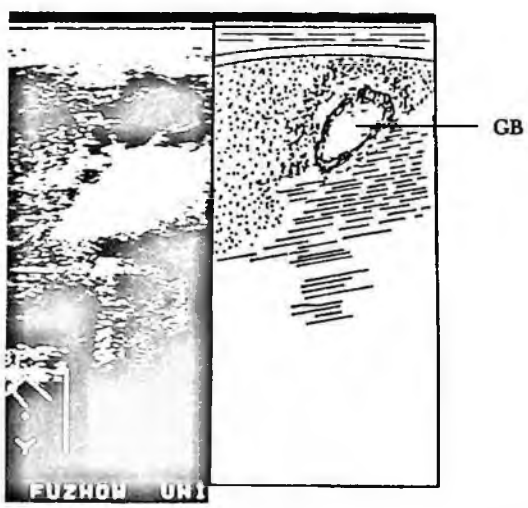

Fig. 5.32 Perforation of the gall bladder, irregular silent area around the gall bladder.

5.5.2.3. *Cholangitis*

The main ones are bacteristic or pyogenic and sclerotic cholangitis. The sonographic changes are as follows:

The sonogram of acute pyogenic cholangitis:

(a) Dilatation of the bile duct, especially dilatation of the extrahepatic bile duct;
(b) Marked thickening of the bile duct wall, hazy outline, the interior of the duct wall has a low echo silent band duct of edema;
(c) Inside the lumen of the file, one may find floating echoes enhancing the echogenic dots, or muddy precitum at its posterior wall;
(d) At the lower segment of the bile duct, gall stone, ascaris and other causes of obstruction may often be found;
(e) Usually combined with changes in acute inflammation of the gall bladder or pathological change of the liver abscess.

Sonogram of sclerotic cholangitis:

(a) Marked thickening of the bile duct wall, the echo is also markedly increased, with a sense of stiffness;
(b) The lumen of the bile duct is not markedly enlarged, but has various degree of local stenosis;
(c) The wall of the gall bladder may have localized thickening and protrudes into the lumen;
(d) The wall of the intrahepatic bile duct increases in thickness and enhances its echo, causing appearance of many "equal sign" short strip-like echo bands inside the liver;
(e) Swelling of lymph nodes at the hilus of the liver, or surrounding the common bile duct, can often be observed;
(f) The wall of the gall bladder is thickened, but the contracting ability of the gall bladder is slowed;
(g) The bile duct usually has no marked dilatation after a fatty meal. Patients with sclerotic cholangitis should be differentiated from whose with jaundice, which is caused by hepatitis. It may also combine with other features of the sonogram, such as enlargement of the liver and spleen, laboratory liver function test or case history, for differentiation.

5.5.3. Tumor of the Bile Duct

5.5.3.1. *Tumor of the Gall Bladder*

Clinical reports of this issue in the past have been rather few. Since the ultrasonographic diagnostic technique has been extensively applied, the use of clinical preoperative diagnosis gradually increased. Benign tumors often have no clinical signs, but sometimes there may be expressions of chronic cholcystitis, which is often found in B-mode ultrasound examination or during operation. Malignant tumors are comparatively rare. They often come with cholecystolithiasis or chronic cholecystitis. According to the statistics, about half of the patients with carcinoma of the gall bladder also have cholecystolithiasis. Therefore, most cases are complicated with signs of stone or inflammation, and are difficult to detect in the

early stages. Ultrasonography is considered the most ideal method for diagnosing gall bladder tumors today.

(a) Benign tumor of the gall bladder

Mostly adenoma or polyp, the sonographic expressions are mostly echo enhanced nodules. It can be round-shaped or long, oval-shaped, either in single or multiple forms. By protruding into the lumen of the gall bladder through one side of the gall bladder wall, its boundary becomes clear and smooth. Sometimes, it may have a lobular shape, and have no acoustic shadows. The diameter of the nodule is usually within 1.5 cm. One of the most important features of differentiating the benign tumor of the gall bladder from cholecystolithiasis is that the former will not move with the change in its body position (Fig. 5.33).

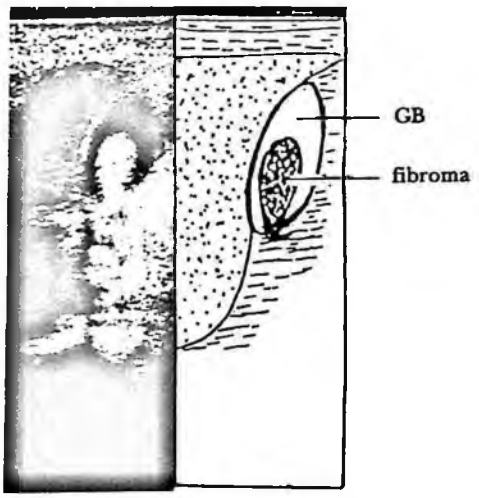

Fig. 5.33 Fibroma in the gall bladder, the boundary of the tumor is smooth.

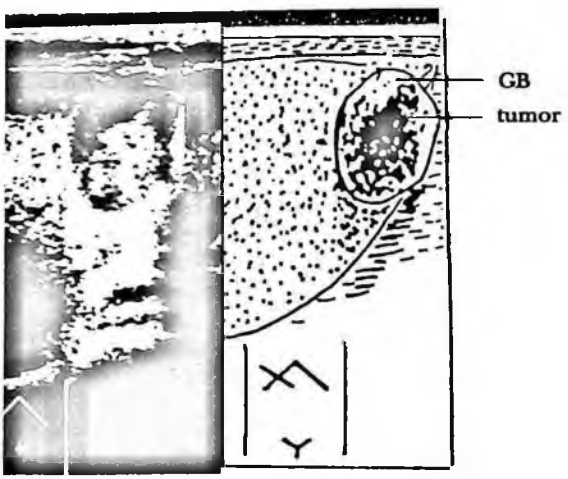

Fig. 5.34 Cholecystocarcinoma (Protuberant type).

(b) Malignant tumor of the gall bladder

Its pathological varieties are adenocarcinoma, squmpus carcinoma and papillocarcinoma. According to its pathological changes and the position of growth, the sonographic expressions can be divided into:

(i) Substantial protuberant type: it is one of the most commonly seen carcinoma of the gall bladder, often regarded as the later stage, appearing as the narrowing or disappearance of the gall bladder lumen and being filled with uneven echoes or low-level echo substances. By protruding into the cavity of the gall bladder from one side of the gall bladder wall, the surface becomes rough and the boundary becomes unclear. It also has no clear demarcation with the liver (Fig. 5.34);

(ii) Fungus type: tumor of the fungus type protrudes into the cavity of the gall bladder, and its edge becomes irregular. The cross-section of the sonogram shows irregular strand-like echoes (Fig. 5.35);

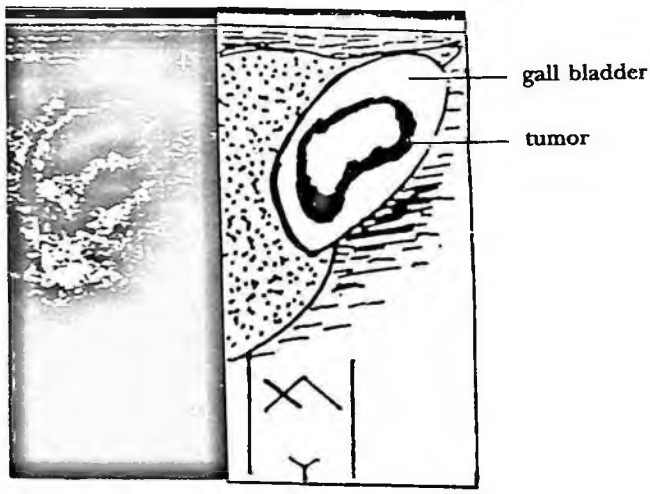

Fig. 5.35 Cholecystocarcinoma (Fungus type).

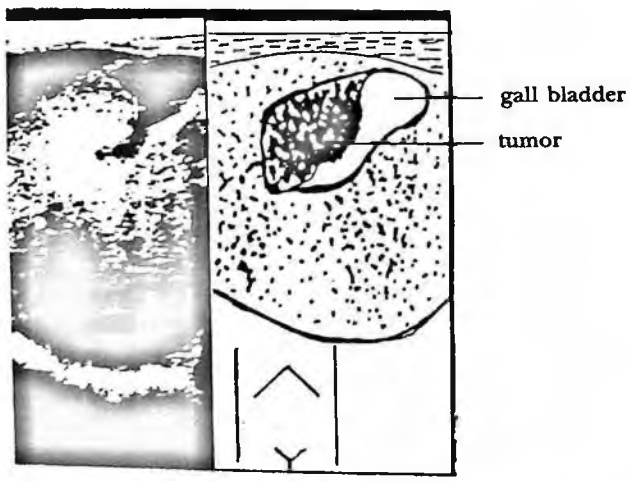

Fig. 5.36 Cholecystocarcinoma (Thickening wall infiltration type).

(iii) Infiltrate thickening type: the gall bladder is irregularly thickened. The echo becomes uneven. Sometimes, it is not easily differentiated from chronic cholecystitis (Fig. 5.36);

(iv) Nodular type: this type usually means it is in the early stages of the carcinoma of the gall bladder. The sonogram is similar to adenoma or polyp. Its boundary is mostly irregular, and requires many follow-up examinations to be differentiated (Fig. 5.37);

(v) Mixed type: this type is often seen in the later stage of carcinoma. Irregular thickening of the gall bladder wall can be found, and at the same time a nodular solid protrusion or fungus-like mass echoes can also be observed (Fig. 5.38).

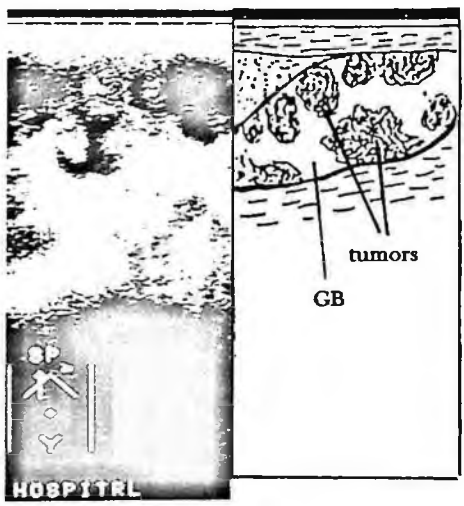

Fig. 5.37 Cholecystocarcinoma (Nodular type).

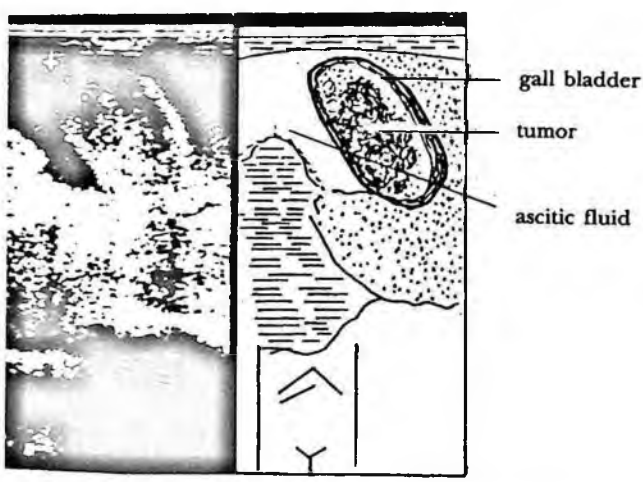

Fig. 5.38 Cholecystocarcinoma (Mixed type).

Besides the above-mentioned direct signs of sonographic images for gall bladder carcinoma, one may also find dilatation of the bile duct, enlargement of the lymph nodes at the hilus of the liver or sign of metastatic pressure in the liver or the pancreas.

5.5.3.2. *Tumor of the Bile Duct*

It is clinically expressed as progressive jaundice. It is mostly seen in malignant tumors. Sonographic expressions display a tumor mass solid image inside the dilated bile duct, which has a rough surface. The wall of the bile duct is often not displayed clearly due to the

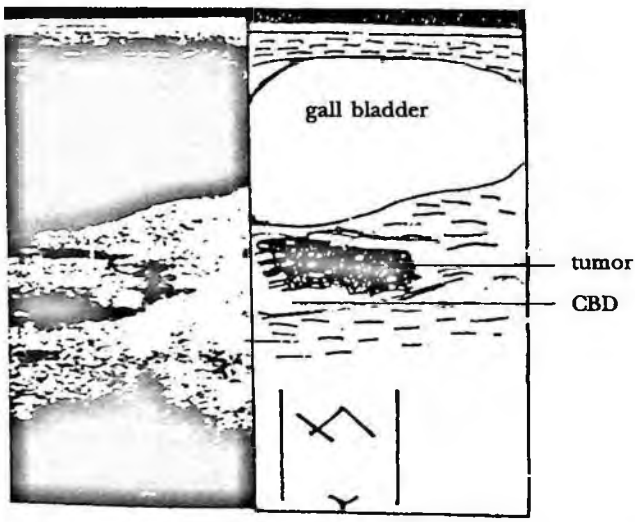

Fig. 5.39 Choledochocarcinoma marked dilatation of the gall bladder.

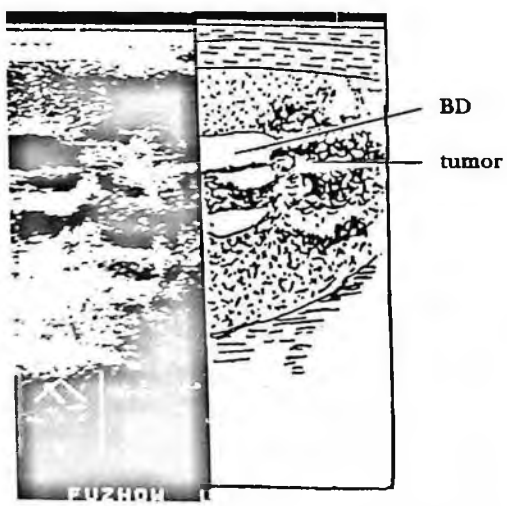

Fig. 5.40 Carcinoma of the right hepatic duct.

infiltration of the tumor mass, or the lumen if it is suddenly broken or it becomes small. The bile duct above the lesion becomes markedly dilatated, and the growing location of the tumor can be ascertained according to the situation. The growing location of the tumor can be ascertained according to the situation of dilatation (lower segment of the bile duct, or upper segment of bile duct, or left or right hepatic duct). Sometimes, enlargement of the lymph nodes at the hilus of the liver, and metastatic focus in the liver or the pancreas may be observed (Figs. 5.39 and 5.40). It should be differentiated from the stone or pathological changes at the head of the pancreas without acoustic shadow.

5.5.4. Ascaris in the Bile Duct

Ascaris in the bile duct is one of the common diseases of the bile duct. Sonographic expressions may find strip-like strong echo bands inside the bile duct. The anterior end appears obtusely round, with the margin mostly smooth. Sometimes, the echoless band of the false body cavity of the ascaris can be found, causing the body of the ascaris to be in two parallel lines. If the ascaris body undergoes peristalsis, the disease can be diagnosed. If it is a long course, and if the ascaris is found dead with fragments, the display will not be clear inside the bile duct, but it is accompanied with various degree of dilatation of the bile duct. The sonogram of the ascaris in the bile duct should be differentiated from secondary echogenic dots or lines inside the bile duct. The bile duct of the latter will not dilatate. Its echogenic dot will not be continuous. However, it will disappear when the direction of examination is changed. In this case the ascaris inside the gall bladder is easier to diagnose, the body of the worm often appears as a round arc or in a tortuous-like shape. Sometimes, one may see masses with an uneven substantial body due to the dead ascaris (Fig. 5.41). Ascaris in the bile duct is usually accompanied by inflammatory change of the bile duct.

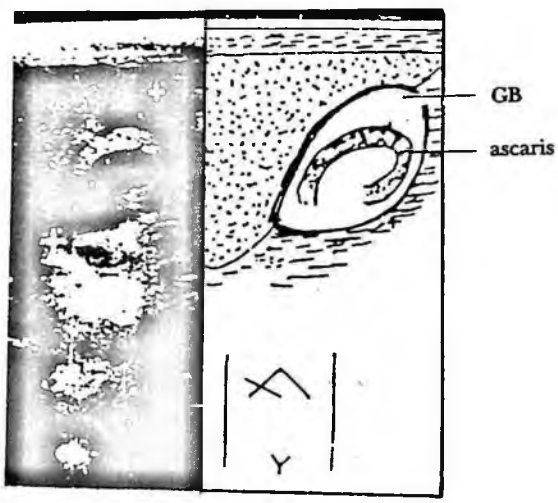

Fig. 5.41 Ascaris in the gall bladder.

5.5.5. Congenital Diseases of the Bile Duct

Congenital abnormality of the gall bladder varys in form, size and position, but it usually does not affect its physiological functions. The two main congenital diseases of the bile duct are congenital cyst of the common bile duct and cystic dilatation of the intrahepatic bile duct. The former shows shuttle cystic dilatation of the common bile duct and the orifice is found to be in communication with the near side bile duct. The cyst usually presses on the gall bladder, and the case is often complicated by the presence of stones or inflammation (Fig. 5.42–5.44). Cystic dilatation of the intrahepatic bile duct is also called Caroli disease. Its sonographic feature is that of a cyst distributed along the main branch of the intrahepatic bile duct, presenting a round or shuttle echoless lumen.

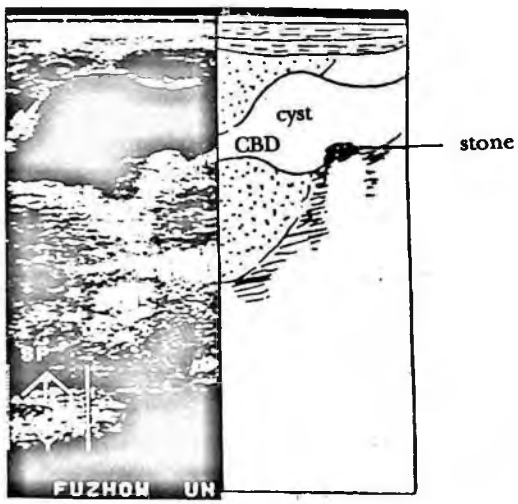

Fig. 5.42 Congenital cyst in the common bile duct with stone.

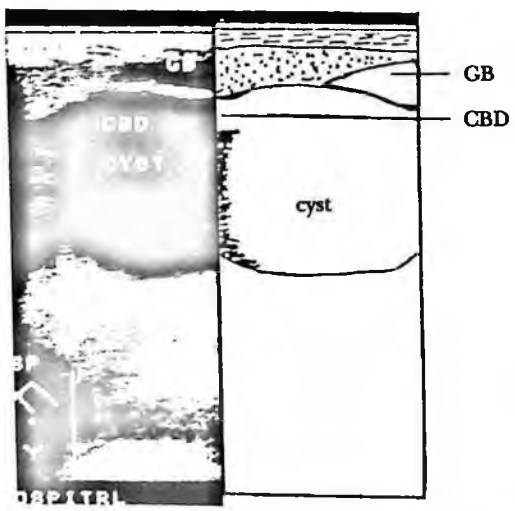

Fig. 5.43 Congenital giant cyst in the common bile duct.

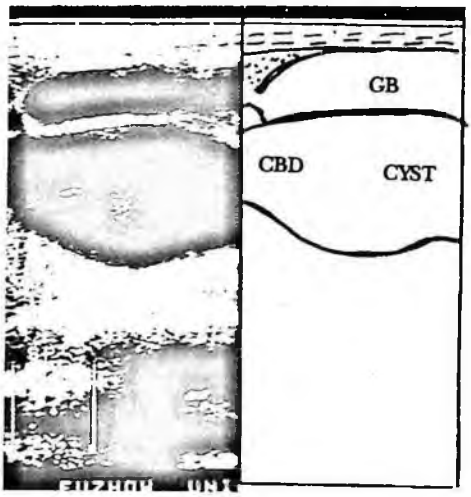

Fig. 5.44 Congenital cyst in the common bile duct.

5.5.6. Sonogram of the Stagnation of Bile Juice

During an ultrasonographic examination, images of the stagnation of bile juice may often be found due to all sorts of causes. The stagnant echo can be found in the gall bladder or dilated bile duct. At the posterior wall of the gall bladder, there is a low-level echo or stagnant band of tiny echogenic dots of medium echo. Its back often shows no acoustic shadow similar to the solid echo, which can be easily misdiagnosed as a tumor. It changes very slowly after changing its body position, but is very quickly restored to its mass. This is called the precipitum of concentrated bile juice, forming the physical state shaking-dissolving phenomenon. This state is mostly found during the obstruction of the bile duct, long periods of fasting, inflammation of the bile duct, hepatitis, and in some patients with liver carcinoma. Once the bile duct is unobstructed, and when retaking food and conditions are improved, the bile juice precipitum disappears right away (Fig. 5.45 and 5.46).

5.5.7. Sonogram of the Bile Gas

In hepatobiliary ultrasonography, strong echogenic dots, similar to the stone in the bile duct, or strand-like light bands running parallel to the portal vein can often be found. This is the sonogram of the gas in the bile duct. The curve is mainly due to biliary tract fistula-biliary tract infection by aerogenic bacilli or due to relaxation of the Oddi sphincter. Many of these cases happen frequently after operating on the bile duct, in particular strongly echogenic dots or hyperechogenic masses when the section perpendicular to the bile duct is much easier to be confused with stone. Sonographic features of the gas in the bile duct are:

(a) Intense gas echo distribution along the bile duct, but presenting "strip-like light band", without dilatation, and bile juice stagnation at the distal end of the bile duct;
(b) Repeated reflection of the gas echo may appear as a "star tail sign";
(c) Strong echogenic dots may move with the change in body positions and present a flickering phenomenon;

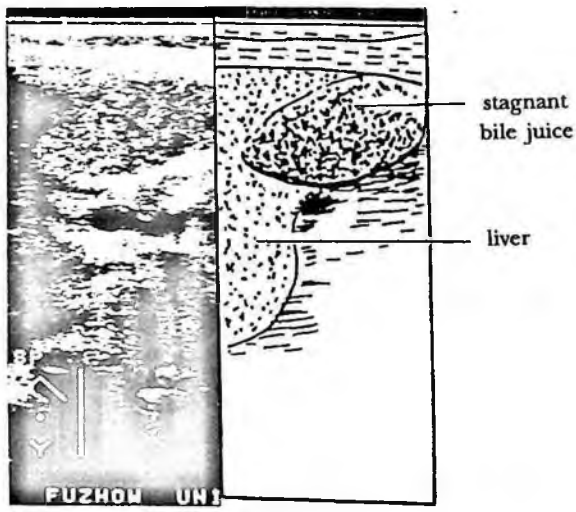

Fig. 5.45 Stagnation of bile juice in the gall bladder filled with precipitum.

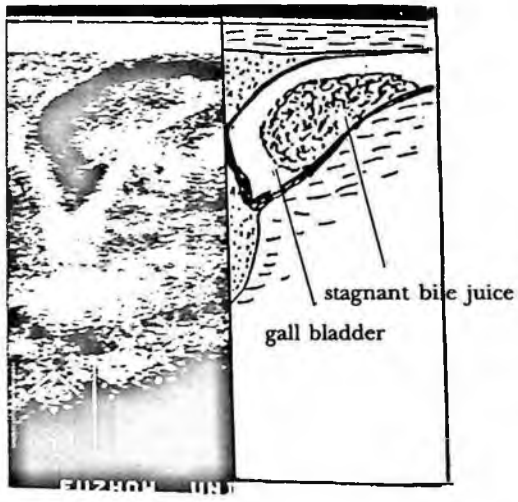

Fig. 5.46 Stagnation of bile juice, precipitum of stagnant bile juice heaped up as a mass.

(d) Its back often has no marked acoustic shadow;
(e) If the sonogram of the gas does not appear after re-checking in the near future, this means that the patient is recovering from the disease, and the gas is being absorbed (Fig. 5.47).

5.5.8. Ultrasonographic Differential Diagnosis of Obstructive Jaundice

Because ultrasonograph may clearly display the condition of dilatation of intrahepatic and extrahepatic bile duct, it is therefore very important to differentiate the location and the cause of obstructive jaundice.

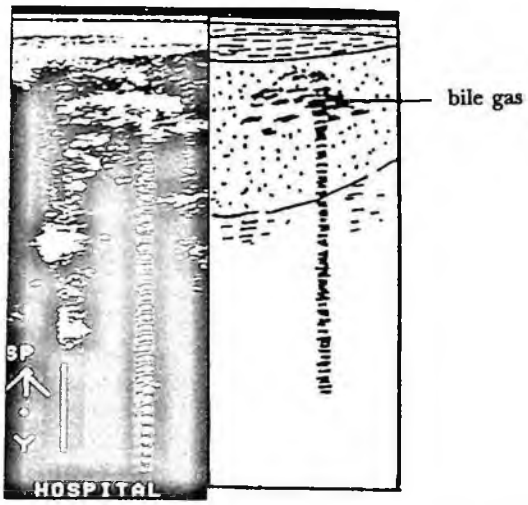

Fig. 5.47 Bile gas in liver with "star tail sign" at its back.

5.5.8.1. *Diagnosis of Obstruction in the Bile Duct*

Intrahepatic bile duct dilatation is often seen in the left and right hepatic duct with a calibre bigger than 3–4 mm (in general, less than 2 mm). The tubular wall of the dilated intrahepatic bile duct is irregular. The sonogram represents a "square" silent area, "star-like" or "brush-like" structure, which is different from the small silent area of the polycystic liver.

The extrahepatic bile duct dilatation is rather easy to be displayed. If the internal calibre at the upper segment of the common bile duct is larger than 7 mm, it presents a "double-barrel shotgun" sign and indicates dilatation of the bile duct. If the lower segment of the common bile duct is bigger than 9–10 mm, it means a definite dilatation, which is the evidence of obstruction. However, a senile patient or a patient after a biliary tract operation (particularly after cholecystectomy) usually has a bigger internal calibre than a normal adult, which may sometimes reach 11–12 mm.

5.5.8.2. *Diagnosis of the Site and Cause of Obstruction*

In accordance with intra and extra-hepatic bile duct dilatation revealed by ultrasonography, it is possible to indirectly infer the site of obstruction:

(a) Dilatation of the whole segment of the common bile duct indicates obstruction of the lower end (Fig. 5.48);
(b) If the internal calibre of the common bile duct is normal and the intrahepatic bile duct is dilatated, obstruction at the hilus of the liver is indicated. If the bile duct at left lobe of the liver is dilated and that in the right lobe of the liver is normal, obstruction at the left hepatic duct is indicated. Otherwise, it will be obstruction at the right hepatic duct.
(c) Under general conditions, the tension in the common bile duct and gall bladder are identical. If the gall bladder is dilatated, it mostly indicates obstruction of the lower segment of the common bile duct. When the tension of the gall bladder and common

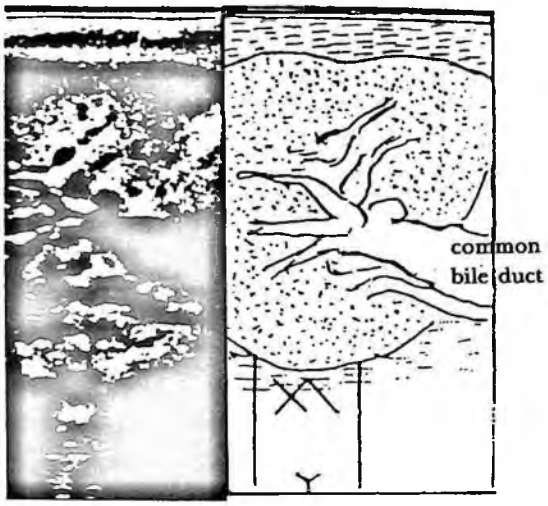

Fig. 5.48 Dilatation of the bile duct in extrahepatic, obstructive jaundice.

bile duct are in a contradictory situation, pathological changes of the gall bladder itself such as chronic atrophied cholecystitis or obstruction at the neck of the gall bladder is indicated.

Most cases of extrahepatic obstructive jaundice are caused by stones in the bile duct, tumor at the head of the pancreas or inflammation. Part of the cases are due to obstruction caused by ascaris and the tumor of the ampulla. The details can be referred to in related sections and chapters of this book. In addition, both clinical and laboratory findings indicate obstructive jaundice. However, ultrasonography shows no dilatation of the intra- or extrahepatic duct, it mostly indicates intrahepatic seclerotic cholangitis. The essential expression is the enhancement of the echoes of the tubular wall.

Chapter 6

Ultrasonographic Diagnosis of Pancreatic Diseases

Lin Liwu

The pancreas is a retroperitoneal viscera. It is a gland with an endocrine function, closely related with the hepatobiliary system. Its surrounding viscerae are complicated. Clinically, many lesions are not easily diagnosed. Although ERCP and angiography are very helpful in the diagnosis of diseases of the pancreas, it has certain traumatic effect and are limited for many lesions. Recently, CT may be used to display the pancreas directly, but it is not popular due to the clumsiness of the equipment. Real-time gray ultrasonography is a rather ideal method used for examining the pancreas nowadays. It will clearly display the pancreas and the pancreatic duct. It is useful in diagnosing pancreatitis and space-occupying lesions.

6.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE PANCREAS

The pancreas lies posterior to the peritoneum, closely adhered to the posterior wall of the abdomen, it is about 12–15 cm in length, 3–4 cm in width, and 1.5–2.6 cm in thickness transversely across the anterior of the 1st–2nd lumbar vertebra in the middle line. Its ventral surface is covered by the peritoneum, and it can be divided into the head, neck, body and tail. The head is flat and wide, located at the right side of the middle line. Its caudal inferior part forms an uncinate process. The demarcation of the neck is unclear and becomes the narrow region between the head and body. The body and tail of the pancreas are usually at the left side of the middle line and have no definite demarcation. The tail is obliquely tilted upwards to the hilus of the spleen, forming an inclining angle about 15°–30° with the head. According to the different sizes of each part, the pancreas can be divided into three forms, namely the "dumb-bell" form: both head and tail are bulky while the body is small; tadpole form: the head of pancreas is big while the tail is tapering gradually (the majority is of this form; and "sausage" form: the sizes of the head, body and tail are practically equal in size.

The projection of the pancreas surface is about 10 cm above the umbilicus (for the upper margin) and about 5 cm above umbilicus for its lower margin.

The lesser omentum and posterior wall of the stomach: the nearby viscerae of the pancreas and the transverse colon are below anteriorly. The head of the right side is curvingly crossed by the duodenum. The tail at the left side is attached to the hilus of the spleen. At the posterior superior body and tail of the pancreas are the left kidney and the left adrenal gland, respectively (Fig. 6.1).

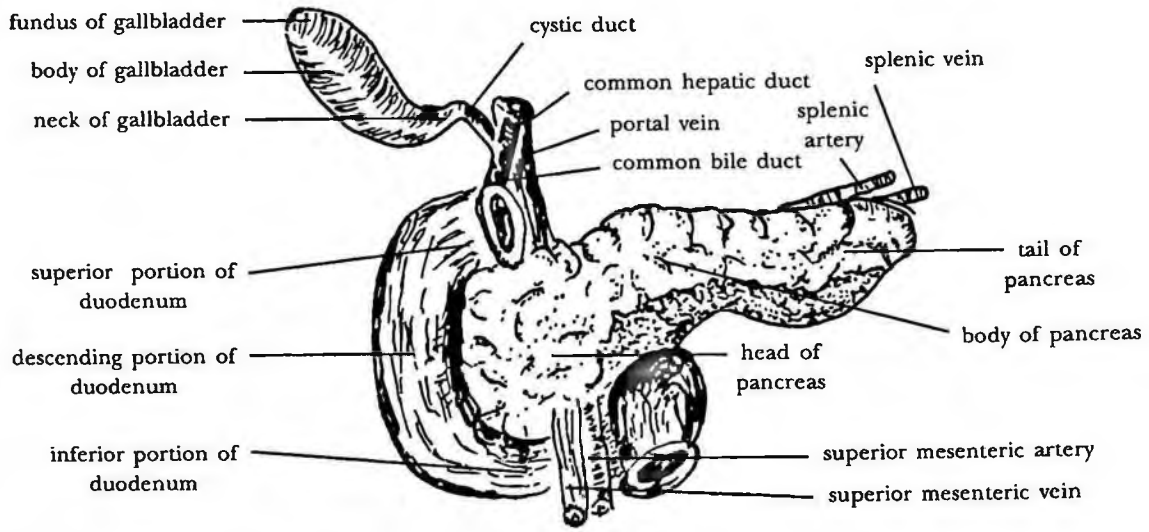

Fig. 6.1 Anatomy of the pancreas.

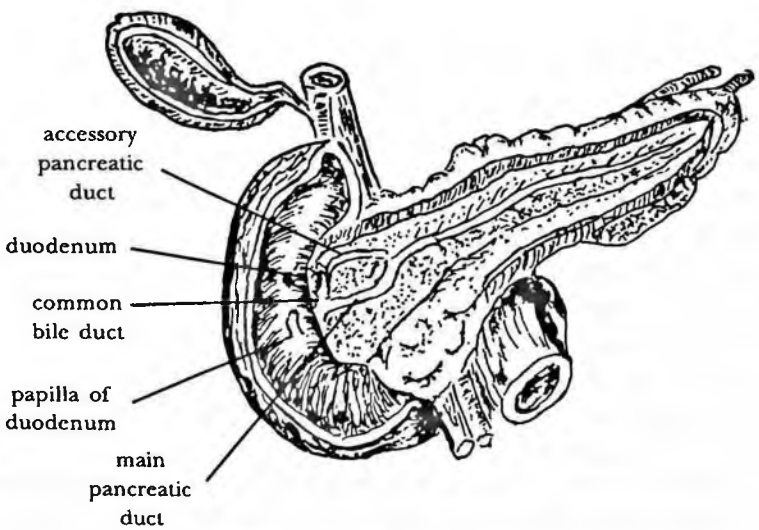

Fig. 6.2 Anatomy of the pancreas and its surrounding ducts.

The channels surrounding the pancreas: as its posterior are the abdominal aorta, inferior vena cava, splenic vein, portal vein, superior mesenteric artery, superior mesenteric vein, left renal vein, and the splenic artery of the posterior superior margin. There is a shallow groove at the right side of the pancreas head. The common bile duct either passes through here to the ampulla and enter into the duodenum lumen, or it passes through the parenchyma of the pancreas head into the duodenum (Fig. 6.2).

Pancreatic juice flows through the small intra lobular duct, small interlobular duct, and the interlobular duct to converge into the main pancreatic duct which is identical to the long axis of the pancreas. It will eventually join with the common bile duct at Vater's ampulla or open into the duodenum papilla independently.

6.2. ULTRASONIC EXAMINATION OF THE PANCREAS

6.2.1. Preparation of the Patient and Points of Attention

Since diseases of the pancreas often relate to the lesion of the liver, gall bladder, and gastrointestinal tract, it is necessary to decrease gas produced by food in the stomach which will affect the transmission of ultrasound. The method is to open the bowels on the eve of the examination, to take light meals one day prior to the examination and take a light laxative before sleep, also fast on the morning of the examination. If there is still too much gas in the stomach, the patient should drink 500–1000 ml of water to serve as a sonolucent window. In this way, not only is the pancreas clearly displayed, but the filled biliary system will facilitate the diagnosis of diseases. For the purpose of increasing the diagnosis rate of pancreatic diseases, the following problems should be noted during examination:

(a) Notice the anatomical position of the pancreas, projection of the physical surface and its relation with the nearby organs.
(b) Gain of the apparatus should not be too big. In general, the sensitivity should be lowered to low level, particularly when using a water-filled stomach as the echolucent window.
(c) When examining the pancreas at the paramedial line, one should carefully observe the interval between the left lobe of the liver and the abdominal aorta or inferior vena cava, and determine whether the pancreas is clearly displayed.
(d) When a low-level echo or echoless area appears at the head of the pancreas, the examiner should differentiate the pancreas from duodenal effusion or dilatation of the portal vein trunk. Examination may be conducted by changing the body position. If the pancreas is still not clearly revealed, the examination should be repeated within a short period (2 to 3 days).

6.2.2. Method of Examination

The examination of the pancreas is generally by means of the supine, decubitus, semidecubitus, sitting, upright or prone position. The sagital selection is often used, cross-

section and oblique sweeping may also be applied. By means of several methods in combination, the rate of resolving the pancreas may reach more than 90%.

6.2.2.1. *Examination Through the Liver*

It mainly uses parenchymal echo of the liver as the echo of the pancreas for reference to reveal the pancreas through the sonolucent window of the liver. It is mainly done by passing the left lobe of the liver through deep inspiration or distension of the abdomen, or from the upright position. This method allows the liver to move down to cover the pancreas and allows flatulence in the intestinal tract to move down to display the pancreas.

6.2.2.2. *Method of Adding Pressure on the Probe.*

Due to the depth of the pancreas in the posterior abdominal wall, particularly when there is too much fat in the abdominal cavity, and when the anterior abdominal wall is too thick, ultrasonographic examination of the pancreas is too difficult. Therefore, compressing the pressure on the probe may be applied. Through intermediate tissues in the abdomen, intestinal gas covered the pancreas, and decreasing the loss of acoustic and energy by reflection and refraction on the entering way of ultrasound, the clearness of ultrasound improves.

6.2.2.3. *Examination Through the Stomach*

This method should be combined with the method of drinking water. Usually, the patient is asked to drink 500–1000 ml of water and examined from the sitting, upright, or right posterior oblique position. The gas in the stomach must be raised up to the fundus of the stomach. The fluid is located at the anterior of the pancreas to improve the sonolucent window, so that the pancreas can be displayed clearly. It should be noted that this method should not be done in the supine position, otherwise the gas in the stomach will be located at the anterior of fluid causing a poor display of the pancreas.

6.2.2.4. *Rotative Examination*

Place the probe on the cross-section of the pancreas, when long axis section of the pancreas body is displayed. By rotating the probe in a clockwise or anti-clockwise direction, the image from long axis section gradually changes to the oblique section or cross-section, thus allowing the whole pancreas to be observed from a different section.

6.2.2.5. *Examination by the Right Decubitus Position.*

When a patient assumes the right decubitus position, a sound beam is passed through the spleen and the left kidney to reveal the tail. At this time, the examiner should notice the differentiation of the spleen and pancreas, the content of the colon, and the tail of

the pancreas. In general, the echo of the spleen is lower than the pancreas, and there is a continuity of the whole body of the pancreas, the content of the colon will disappear after changing the body position and defecation.

6.2.2.6. *Examination of the Tail of the Pancreas*

The longitudinal section examination is from the abdominal aorta sweeping down to the inferior vena cava. Besides the above-mentioned right decubitus position, it can also be tested through the spleen and left kidney to display the pancreas tail. It is also possible to examine through the back and pass the left kidney, or combined with the method of drinking water.

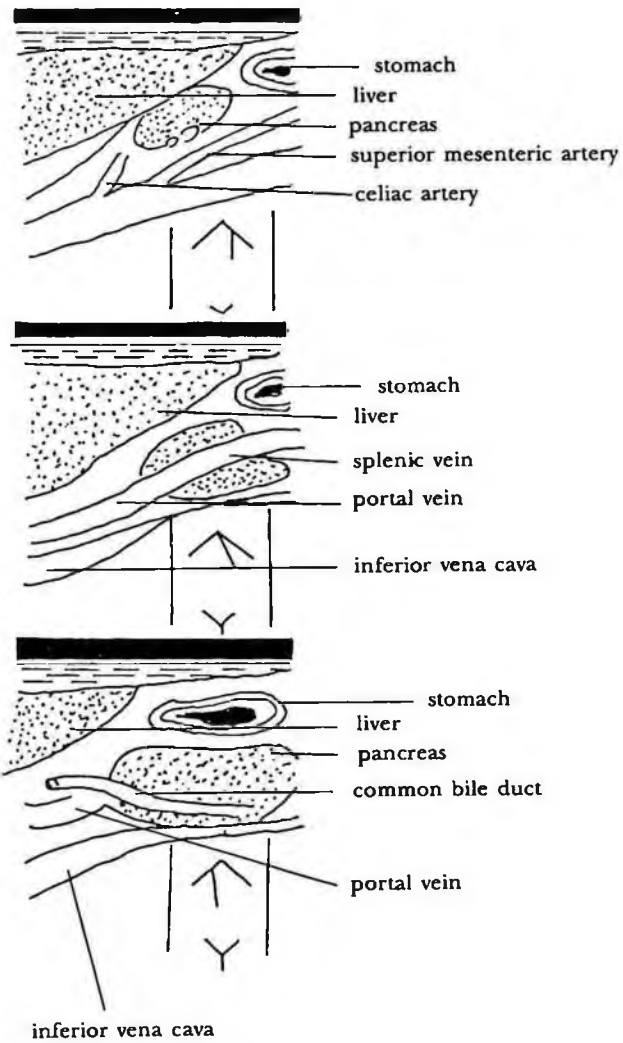

Fig. 6.3 Sketch map of the longitudinal section examination of the pancreas.

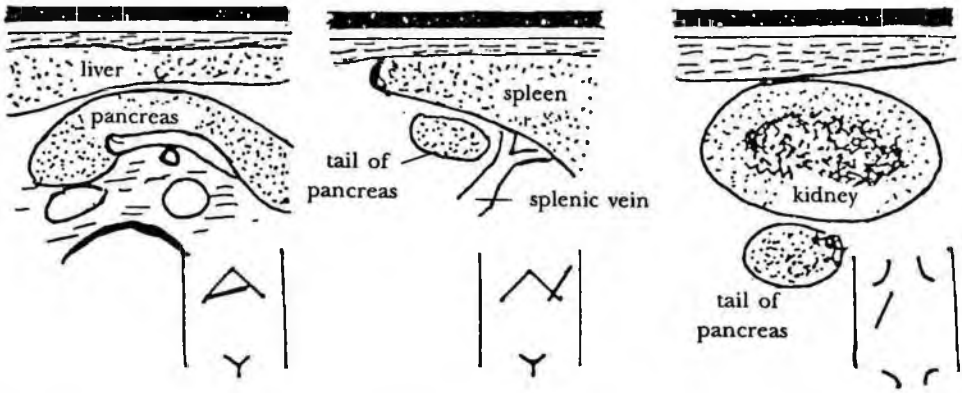

Fig. 6.4 Sketch map of the examination of various parts of the pancreas. Left fig.: Cross-section of the upper abdomen; Middle fig.: Left intercostal oblique section; Right fig.: Left back oblique section.

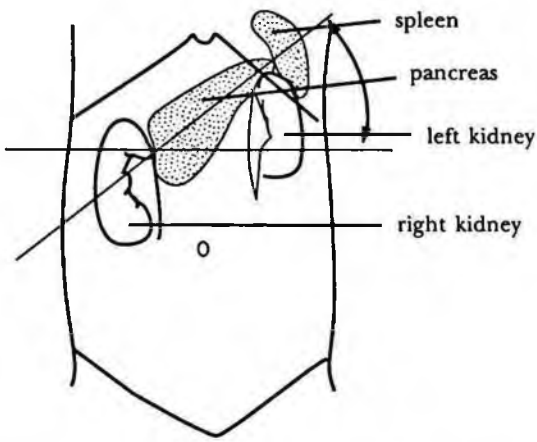

Fig. 6.5 Sketch map of the location of the cross-section of the pancreas on the upper abdomen.

6.2.2.7. *Examination of the Pancreas Head*

By examining from the longitudinal section and sweeping from the abdominal aorta down to the inferior vena cava, one can find the sonogram of the pancreas head which is located in front of the inferior vena cava. Inwards one may find the uncinate process, which is at the posterior of the superior mesenteric vein. By cross-section examination, i.e make continuous parallel sweeping downwards over the cross-section of the pancreas body, readily finds out the head. The uncinate process is the inward protuberance, which is close to the superior mesenteric vein. By the right oblique examination, a patient on right posterior oblique position can let gas into the duodenum and rise up to the stomach. This method may clearly display the head of the pancreas, or it may be combined with the application of the drinking water method (Figs. 6.3–6.5).

6.2.2.8. *Examination of the Pancreatic Duct*

The pancreatic duct is in the parenchyma of the pancreas along the direction of the pancreas. The running direction for each part of the pancreatic duct is not identical. When conducting the examination, the examiner should make the sound beam perpendicular to the pancreatic duct in order to display the pancreatic duct easily. Therefore, examination of the pancreatic duct in the body of the pancreas should be taken from the cross-section, and let the probe be perpendicular to the anterior abdominal wall. For the pancreatic duct at the pancreas head, it is necessary to take an oblique section by using the probe to make an angle of 15°–30° with the horizontal cross-section, and perpendicular to the anterior abdominal wall, or sweeping by the probe which is perpendicular to the right side of the trunk (right upper side of axilla cross-section to examine the head of the pancreas through the liver). A normal pancreatic duct usually presents either a single line or a parallel double of an echo enhancement in the parenchyma of the pancreas. Its widest diameter does not exceed 2 mm, and can be displayed easily in the body of the pancreas. It runs in a parallel direction to the splenic vein (Fig. 6.6).

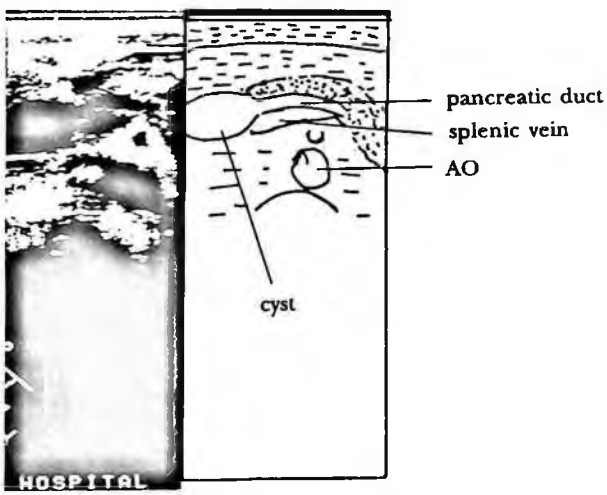

Fig. 6.6 A cyst in the head of the pancreas causing dilatation of the pancreatic duct.

6.2.2.9. *Observation of Blood Vessels Surrounding the Pancreas*

There are many blood vessels surrounding the pancreas. They come from the abdominal aorta and its branches, such as the abdominal aorta, celiac artery, splenic artery, hepatic artery and superior mesenteric artery. Those coming from the inferior vena cava are the inferior vena cava and the left renal vein. Those coming from the portal system are the portal vein, splenic vein and superior mesenteric vein. When detecting along the running direction of the blood vessel, the examiner can move the probe clockwise or anti-clockwise to observe the entire course of the blood vessel. Special attention should be paid to the abnormal course of splenic vein inside the pancreas, which may be mixed up with the pancreatic duct. At this time, the examination should follow the entire course of blood vessel, or adopt the Doppler examination to determine its status (Fig. 6.7 and 6.8).

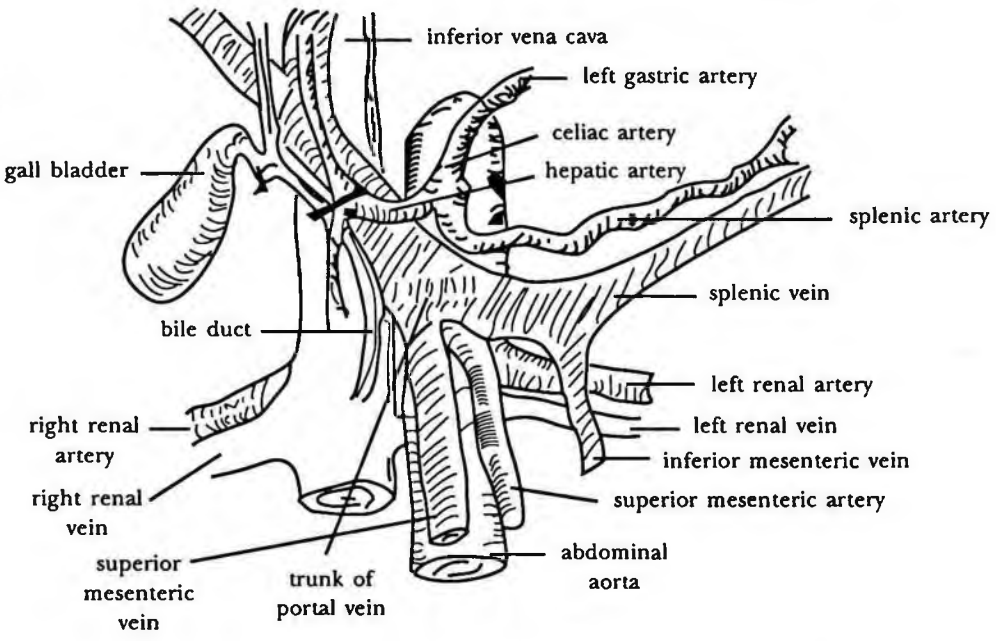

Fig. 6.7 Sketch map of the anatomy of the blood vessels surrounding the pancreas.

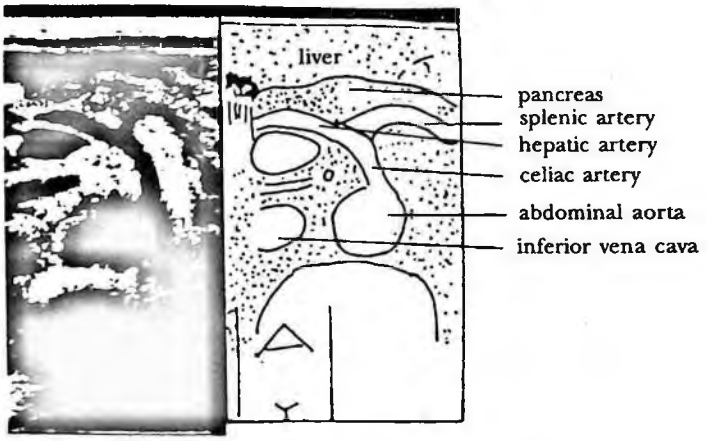

Fig. 6.8 Sonogram of the blood vessels surrounding the pancreas.

In case the abdominal wall is too thick and there is too much gas in the intestine, causing unclear display of the pancreas and its surrounding blood vessels, the above methods such as deep inspiration, distension of the abdomen or adding pressure on the probe, drinking water, or examination by multiple body position to eliminate gas, can be used to improve the examination technique and the quality of the sonogram.

6.3. NORMAL SONOGRAM OF THE PANCREAS

A normal pancreas has no capsule and its texture is soft. The boundary of the sonogram is fine, smooth and regular. Sometimes, the interface with the surrounding tissue is not clear. The cross-section can reveal an oval-shaped pancreas head, and the body and tail are at the left side. At the longitudinal section, the examiner may find a triangular-like pancreas body or an oval-shaped pancreas head between the left lobe of the liver and the abdominal aorta or the inferior vena cava, with a smooth boundary and regular, homogeneous texture. Normal echo of pancreas is similar to the liver (or somewhat lower than that of the liver). As the age advances, the echo of the pancreas is enhanced. The echo of an old man's pancreas may be stronger than that of the liver. If the pancreas is examined through a water-filled stomach, the echo of the pancreas will be markedly increased.

A normal outline of the pancreas is usually determined by the anatomical structure of its surrounding. At present, there is no unified standard for the normal value of the pancreas — mostly by measuring the thickness of each part (anteroposterior diameter) for the standard or anterior posterior diameter of the pancreas. In Table 6.1, the normal standard of both foreign and domestic authors, and the author of this book can be used as reference (Fig. 6.9 and 6.10).

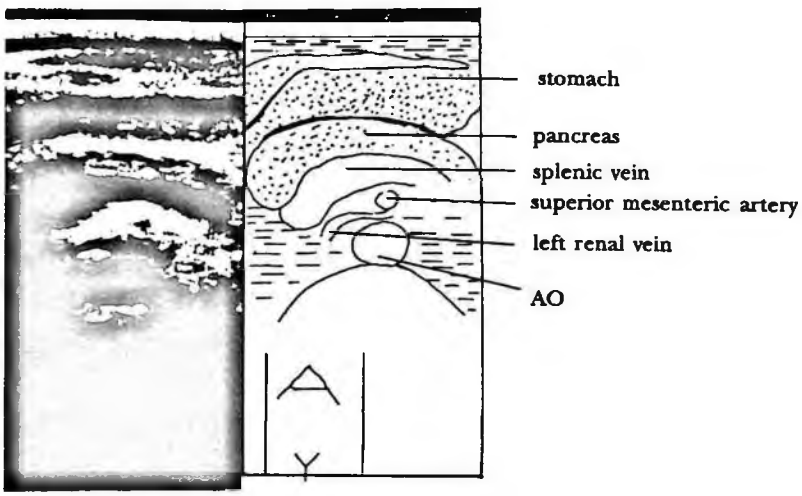

Fig. 6.9 Sonogram of a normal pancreas.

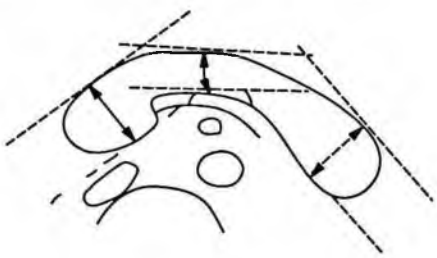

Fig. 6.10 Method of measuring the thickness of various parts of the pancreas.

Table 6.1 The Measured Value (mm) of Thickness of Different Parts of a Normal Pancreas by Different Authors

Author	Case	Head	Neck	Body	Tail
Haber et al. (1976)	382	27 ± 7		22 ± 7	
Weili et al. (1977)	135	11 ~ 30	7 ~ 10		
DeGraef et al. (1987)	100	cross sec. 20.8 ± 4 long. sec. 20.1 ± 3.9	9.5 ± 2.6 10 ± 3	11.6 ± 2.9 11.8 ± 3.6	
Fu Tian Shou Dao (1978)	382	post. ant. 27 ± 7 diameter long. diameter 36 ± 12		22 ± 7 30 ± 6	24 ± 4 21 ± 4
Arger et al. (1979)	407	18 ± 1.2		17.5 ± 1.4	17.5 ± 1.1
Capital Hospital Beijing (1982)	male 294 female 603	16.66 ± 1.38 16.36 ± 1.36		9.76 ± 1.53 9.46 ± 1.38	8.96 ± 1.15 8.81 ± 2.40
Union Hospital affiliated to Fujian Medical University (1982)	349	17.5 ± 3.1		14.1 ± 2.9	15.1 ± 2.9

6.4. ANALYSIS OF THE SONOGRAM OF AN ABNORMAL PANCREAS

6.4.1. Enlargement of the Pancreas

If the size of the pancreas is bigger than the standard value given above, it means there is an enlargement of the pancreas. It is divided into diffusive enlargement and localized enlargement. The former is mostly seen in diffusive pancreatitis, and the latter is mostly seen in localized tumor or localized pancreatitis.

6.4.2. Intrapancreatic Tumor

It can be divided into:

(a) Commonly seen echoless tumors are pseuodocyst, hematoma, congenital cyst, and liquified necrosis of the pancreas in acute pancreatitis. A pseudocyst often results after acute pancreatitis. An echoless tumor appears in the nearby pancreas or distant organs like the lesser omentumbursa or perirenal space, often there is an echo enhancement effect at its posterior. Posterior of hematoma is often without echo enhancement. The wall of a congenital cyst of the pancreas is smooth with good echolucent, it is mostly combined with polycysts in the liver and the kidney. Necrotic liquefaction of the pancreas may show an echoless area embracing the surrounding tissues of the pancreas. An echo focus of tissue fragment may be displayed due to sinking by gravitional force, and move with the change of its body position.

(b) Low-Level echo tumor is lower than the parenchymal echo of the nearby pancreas. They are mainly pancreas carcinoma, tumor of Langerhans's cells, lymphoma, focal pancreatitis, and small cystic tumor. The carcinoma of the pancreas may result in the partial enlargement of the pancreas, uneven strength of echo, and irregular boundary. The tumor located at the head of the pancreas is often seen with dilatation of the bile duct and pancreatic duct. It may also be found with stenosis or obstruction of the surrounding blood vessels due to pressure. Lymphoma is usually accompanied by enlargement of the lymph nodes at the side of the aorta or other places like the mesenteric lymph nodes. Sometimes hematoma may present low-level echo of tumor, but its internal echo is rather even. Focal pancreatitis is not easily differentiated from carcinoma of the pancreas.

(c) The tumor of strong echo is usually accompanied with different degree of acoustic shadow. Commonly seen are carcinoma pancreas, focal calcification of pancreatitis, stone in the pancreatic duct, gas in the pancreatic abscess. For stone in the pancreatic duct, the abscess may move with the change in the body position. Carcinoma of the pancreas with strong echo is seldom seen.

6.4.3. Extrapancreatic Tumor

Similarly it can be divided into:

(a) Extrapancreatic echoless tumor. It is commonly seen in the dilatation of the gall bladder, congenital cyst of the common bile duct, aneurysm, and renal or suprarenal cyst. The gall bladder and cyst of the bile duct are easy to differentiate; aneurysm may have expansive palpitation, sometimes it may be found with blood embulus within a cystic tumor or focal calcification of the tubular wall. In the case with palpitation it is not distinctive and can be differentiated with Doppler. Aneurysm may be derived from the abdominal aorta and its branch hepatic artery, splenic artery, celiac artery and superior mesenteric artery. The author has mistaken a case of splenic aneurysm cyst of the tail of the pancreas due to unclear palpitation, therefore it deserves attention.

(b) Extrapancreatic low-level echo tumor. Most commonly seen are the enlarged para-abdominal aorta lymph nodes crossing over the abdominal aorta and inferior vena cava, causing the superior mesenteric artery to change its position (Fig. 6.11). Besides these, there are enlargement of lymph nodes in abdominal cavity, including lymph node plexus in the abdominal cavity, superior mesenteric lymph nodes, lymph nodes in the hilus of the liver, and paracardial lymph nodes between the left lobe of the liver and abdominal aorta. Enlarged lymph nodes with low-level echo, and smooth boundary and

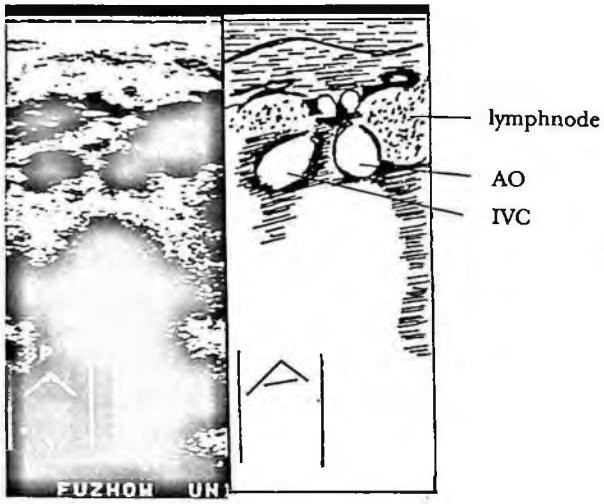

Fig. 6.11 Enlargement of the lymph node at the para-abdominal of the aorta, behind the tail of the pancreas.

are mostly seen in lymphosarcoma or tuberculosis. A tumor in the stomach may have many expressions. It will be clearly displayed after drinking water. The tumor in the left kidney or the left suprarenal gland usually appears with low-level echo tumor at the tail of the pancreas. It is necessary to observe the tail of the pancreas carefully, as well as the relation between the tumor and the kidney.

(c) Extrapancreatic strong echo tumor. The extrapancreatic tumor like calcification of the wall of the aneurysm or other tumor, may all appear with strong echo accompanied with acoustic shadow.

In analyzing the tumor in the pancreas and the tumor surrounding the pancreas, we should pay attention to differentiate the feature acoustics and artifact.

(i) An echoless tumor may be a substantial tumor such as the enlargement of the lymph node. Organization of hematoma may appear as an echoless sonogram.

(ii) The sonogram which illustrates a tumor with an echo is not necessarily a substantial tumor, for example abscess or hematoma may appear tump with echo.

(iii) The echo condition at the posterior of the tumor. In general, the posterior of the tumor with fluid has an echo extraplacement effect and posterior of a substantial tumor does not have an echo enhancement effect. However, for the pancreas and its surrounding tumor due to the relationship between its position and nature, the tumor with fluid such as abscess and hematoma may not necessarily have posterior echo enhancement on the contrary, in the case of the substantial tumor like lymphoma, its posterior may have an echo enhancement effect.

(iv) Pay attention to the examination of the organs near the pancreas while examining the pancreas. In the meantime, one should notice the examination of biliary system, the liver, kidneys, spleen, and retroperitoneal visceral tissue in the abdominal cavity in order to identify the nature and position of the lesion.

6.5. ULTRASONOGRAPHIC DIAGNOSIS OF COMMON DISEASES OF THE PANCREAS

6.5.1. Acute Pancreatitis

Clinical expression are upper abdominal pain and fever. The main pathological changes are inflammatory congestion edema and fluid effusion. Serious cases show hemorrhage, necrosis of tissue and liquefaction.

Ultrasonographic expression:

(a) The volume of the pancreas is markedly enlarged. The outline becomes hazy with diffusive enlargement. Localized enlargement is difficult to differentiate from the tumor.
(b) Low echo inside the pancreas is mostly even. In case of hemorrhage or necrosis, it may appear as an echoless tumor.
(c) A pseudo-cyst may surround the pancreas. Diffusive acute pancreatitis is relatively easy to diagnose. A localized one should be differentiated from a tumor. The latter usually has a long history of dull upper abdominal pain, the patient appears thin and has a history of anorexia. The sonogram reveals low-level echo, uneven echo tumor often with an irregular boundary and is helpful when differentiating (Fig. 6.12).

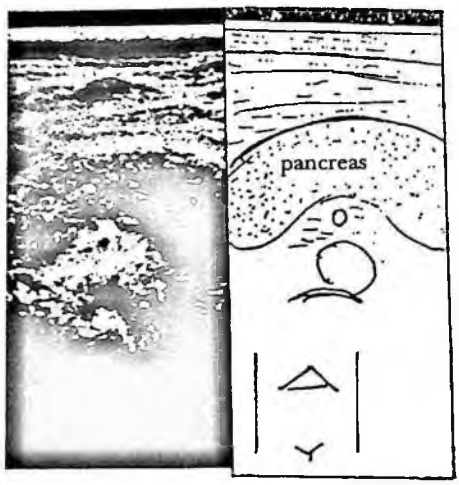

Fig. 6.12 Enlargement of the pancreas in acute pancreatitis.

6.5.2. Chronic Pancreatitis

This is mostly due to repeat attacks or protract from acute pancreatitis. The main pathological expression is expansive fibrosis and formation of small nodules. In case it is inter-glandular folicle fibrosis mostly covers the entire pancreas while interlobular fibrosis mainly involves the head of pancreas. The pancreatic duct usually has an adhesive structure with partial dilatation. It may even appear as a cyst, which can easily induce calcification and stone in the pancreatic duct.

Sonographic expression:

(a) A change in the volume of the pancreas. The pancreas may enlarge diffusively and mildly. It may also have localized enlargement. At this time, it should be differentiated from the tumor of the pancreas. In case of marked fibrosis, the volume of the pancreas may become smaller and every part of the sonogram becomes markedly thin.
(b) Abnormal internal echo. Non-homogeneous echoes inside the pancreas are mostly enhancement echogenic dots and are disorderly. It may appear big or small. An unequal sized echoless area shows there is a retention cyst.
(c) The pancreatic duct may be dilated, become big, unevenly small or appear twisted.
(d) Sometimes, there may be a strong echo of stone or vestige of ascaris (Fig. 6.13). The margin is often irregular and unclear.
(e) Due to the stretching of the pancreas, the surrounding veins often become adherent and dilatates.
(f) The biliary tract system changes, for example in chronic cholangitis or dilatation of the bile duct.

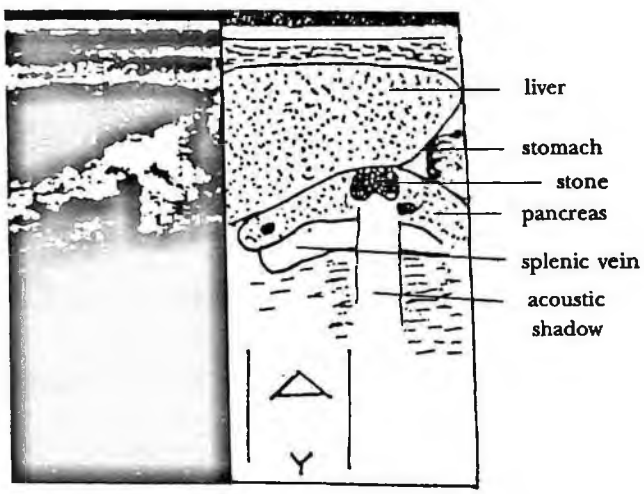

Fig. 6.13 Stone in pancreatic duct in chronic pancreatitis

6.5.3. Pancreatic Cyst

Commonly seen pancreatic cysts are pseudopancreatic cysts, congenital cysts, and retention cysts. Among them, the pseudopancreatic cyst is the most frequently seen, it mostly developes after pancreatitis or trauma. Due to the inflammatory effusion of pancreatic tissue, the necrotic hemorrhage or retention of extrapancreatic secretion form a cystic effusion by the embracement of fibrous tissue and omentum (singular or poly in number) often developed at the tail. The sonogram expresses round, echoless silent area of different sizes surrounding the body and tail of the pancreas, and reach to the pelvic cavity. It should be differentiated from an ovarian cyst. The latter's cystic wall is smooth with good internal echolucence, while the content of the pseudocyst is complicated with multiple echo changes. Echogenic dots and

light clusters may be found. The congenital cyst is the abnormal development of a pancreatic glandular folicle or duct, usually accompanied by cystic changes in the liver, kidneys or the other organs. The special features of the sonogram consists of unequal number and unequal sized echoless silent areas in the pancreas, a rather good internal echoluence, and no disordered echogenic dots or hyperechogenic mass or adhesion to the surrounding (Figs. 6.14 and 6.15).

A retention cyst is the retention of pancreatic fluid by pressure or by blockage of the pancreatic duct, usually accompanied by chronic inflammation, stone or tumor. The cystic wall is clear and its outline is regular (Fig. 6.16).

Besides the three kinds of cysts mentioned above, obtaining a cyst in the pancreas is also possible for a patient suffering from echinococcosis. The sonogram reveals complete cystic

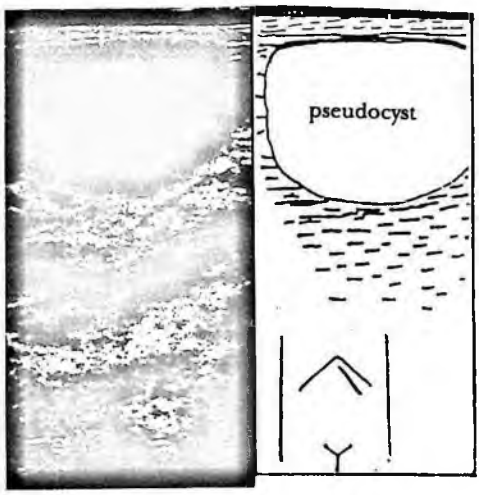

Fig. 6.14 Pseudocyst at the tail of the pancreas.

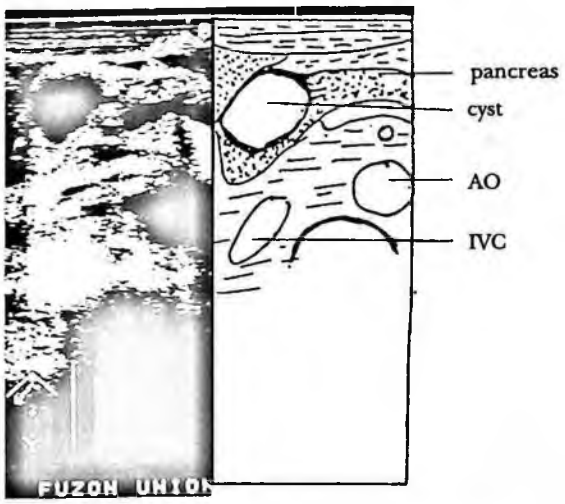

Fig. 6.15 Congenital pancreatic cyst.

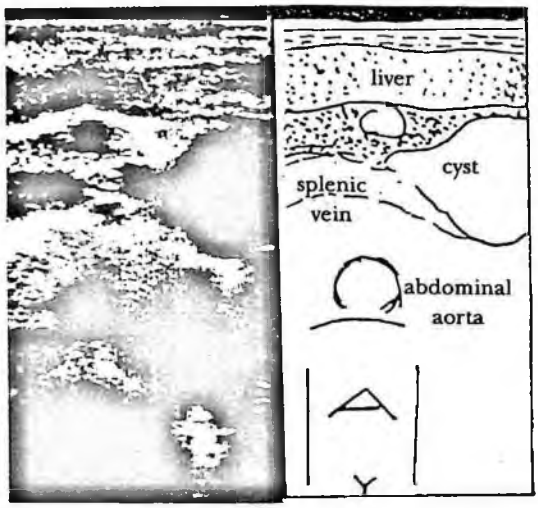

Fig. 6.16 Retention cyst of the pancreas (developed from the pancreatic tumor).

silent zones and sometimes a hyperechogenic mass echo of the daughter cyst or scolex may be found. In cases where a similar echo change of another organ is found, the diagnosis is not difficult.

6.5.4. Pancreatic Tumor

Benign tumors of the pancreas, such as the pancreatic dysticadenome (Fig. 6.17), are rare while malignant tumors such as carcinoma of the pancreas are common. There is an increasing trend of the latter being seen nowadays, in which about 2/3 grow at the head of pancreas and the rest at the body or tail of the pancreas.

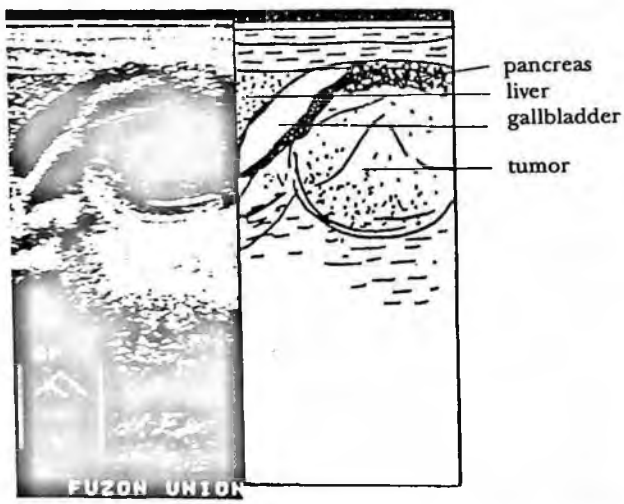

Fig. 6.17 Cystiadenoma of the pancreas at the head of the pancreas.

(a) Clinic and pathology of carcinoma of the pancreas: The majority of the patients suffer from radiated upper abdominal pain, emaciation, anorexia, and 25% of them get jaundice in the prodromal system. The majority of the cases involving carcinoma of the pancreas are derived from adenocarcinoma of the epithelium of the duct, while the rest are derived from the grandular follicle. Substantial construction is hyperplasia of cells, sometimes with secretary function, may find mucinous or colloidal material. If hemorrhage develops or necrosis, pathological change will be complicated. With a slow pathological course, there will be hyperplasia of the fibrous connective tissues, adherence to the surrounding organs, and stenosis or blockage of the pancreatic duct, which results in cystic dilatation. The pathology of chronic pancreatitis is similar to that of the retention cyst.

(b) Sonographic expressions:

(i) The pancreas shows localized and diffusive enlargement, and loses its normal form. Its outline and boundary are often irregular and confused, and it often infiltrates to the surrounding tissues;

(ii) Its internal echoes are mostly low-level echoes. The rest are strong echoes or non-homogeneous medium echoes, and a few are echoless. According to the report from Union Hospital, which is affiliated to Fujian Medical University, in 1986, 25 cases of carcinoma of the pancreas have been proved by surgery and pathology. 70% of them are presented by preoperative sonogram as low-level-echo tumors; two cases appeared as diffusive pathological changes similar to the change of chronic pancreatitis, and two cases appeared as cysts at the tail of the pancreas;

(iii) Once necrotic liquefaction occurs in the carcinoma of the pancreas, a fluid-silent area may be found in the tumor. Its boundary is irregular and non-homogeneous echogenic dots of necrotic tissue may be found in its interior.

(iv) When carcinoma develops to a certain degree, it will press on the surrounding organs, developing signs of crushing them. Some examples of the signs are displacement stenosis or inducing stenosis, and displacement of the portal vein,

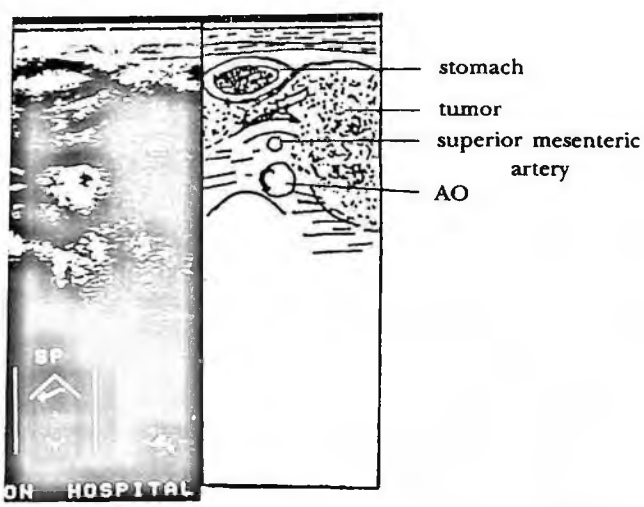

Fig. 6.18 Tumor at the tail of the pancreas.

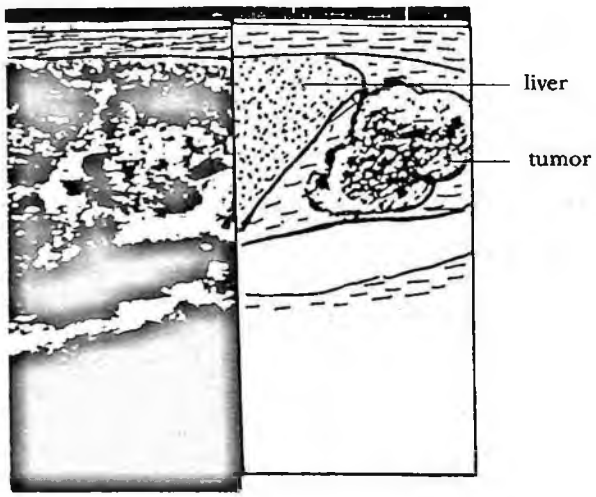

Fig. 6.19 Sonogram of a tumor at the body of the pancreas (longitudinal section).

Fig. 6.20 Sonogram of a tumor at the tail of the pancreas (transverse section).

splenic vein, or superior mesenteric artery and vein. There may be signs of interruption, causing the surrounding viscera to be deformed or displaced;

(v) Carcinoma of the pancreas may infiltrate and metastasize to the surrounding viscera, and there may be signs of metastasis occurring in the surrounding lymph nodes (Figs. 6.18–6.20).

(c) Characteristics of carcinoma of the head of the pancreas:

(i) About 90% of carcinoma of the head of the pancreas will cause obstruction to the common bile duct, inducing dilatation to the bile duct at the upper end of the obstruction. Its internal diameter during the late stages may reach 2 cm, or even more than 3 cm. Some patients may show dilatation of the common bile duct

before having jaundice, which is helpful for the early diagnosis of the carcinoma of the head of the pancreas. However, it must be noted that about 5–10% of the patients with carcinoma of the head of the pancreas do not experience dilatation of the bile duct. This may be due to the tumor being rather small or the location of growth. The tumor may not press on the orifice of the common bile duct at the papilla, and most of the time the small tumor at the uncinate process does not cause dilatation of the common bile duct (Figs. 6.21 and 6.22).

(ii) The pancreatic duct presenting wavelike dilatation is also a common sign of carcinoma of the head of the pancreas. A normal pancreatic duct is not over 2–3 mm, if it is over 3 mm thus indicates dilatation, which can often reach

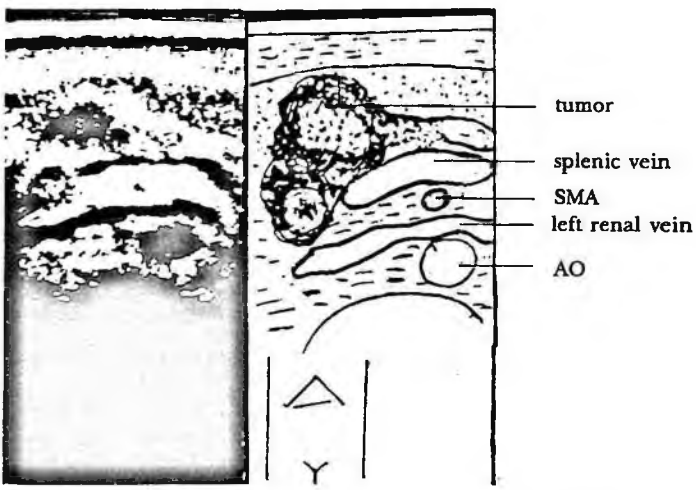

Fig. 6.21 Sonogram of the tumor at the head of the pancreas.

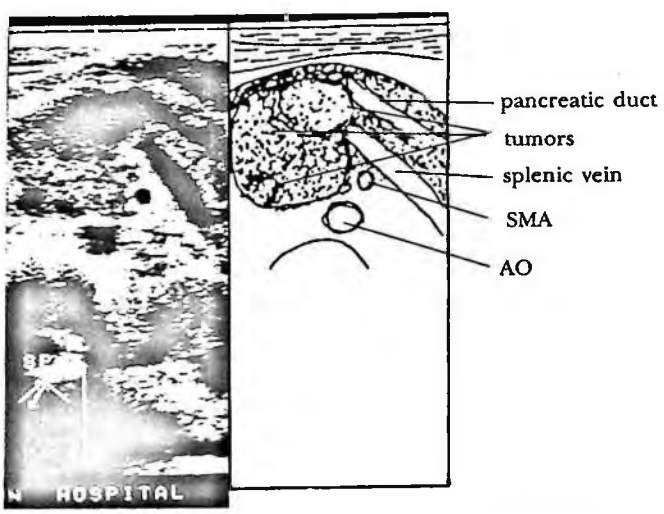

Fig. 6.22 Sonogram of the tumor at the uncinate process of the head of the pancreas.

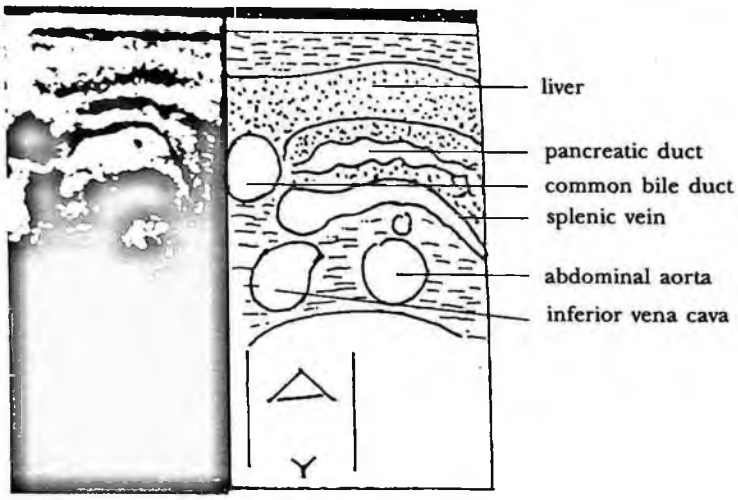

Fig. 6.23 Wave-like dilatation of the pancreatic duct.

5–10 mm. The dilatation of two ducts (common bile duct and pancreatic duct) and finding tumor at the head of the pancreas are reliable signs of ultrasonograph diagnosis of carcinoma of the head of the pancreas (Fig. 6.23).

(iii) Signs of pressure on the surroundings: Besides pressing on the common bile duct and the pancreatic duct, the pancreatic head carcinoma may also grow posteriorly, exerting pressure on the inferior vena cava, and causing it to become small and displaced. Signs of venous dilatation at the posterior end of oppression may also be found.

(iv) Signs of infiltration and metastasis to surrounding organs or metastasis to surrounding lymph nodes.

According to the Union Hospital, which is affiliated to Fujian Medical University, a positive rate of ultrasonographic diagnosis of the carcinoma of the head of the pancreas is 88% (16/18), while the positive rate of diagnosis for the body and tail is only 75% (12/16). Carcinoma of the body and tail, particularly the diffusive type, is easily confused with chronic pancreatitis. This deserves attention, so it is better to recheck within a short period of time. In addition, pancreatic carcinoma which causes cystic changes should be differentiated from other pancreatic cysts. At the same time, this disease should be differentiated from tumors in the organs surrounding the pancreas, such as the retroperitoneal tumor, lymphoma, enlargement of lymph nodes, and particularly the tumor at the uniconate process.

(d) Other kinds of tumors of the pancreas:

(i) Langerhan's cell tumor: The majority of the Langerhan's cell tumor are benign and a minority are Langerhan's cell carcinoma. Langerhan's cell tumor is commonly seen in male adults. Clinically, the characteristics of having this tumor is getting hypoglycemia and related problems in the nervous system. The tumor appears as a round, oval or irregular nodule. Sonographic expression: These tumors are mostly smaller than 1 cm with a smooth surface. They are located at the tail region, and have complete capsules. Since the volume of the tumor is rather

small, the internal echo is weak. It is not easily differentiated from the pancreatic tissue, hence it must be observed carefully. They seldom have pressure symptoms. The volume of Langerhan's cell carcinoma is often big, with no capsule, no regularity and often accompanied by signs of hemorrahage. If local infiltration occurs, it is not easily differentiated from carcinoma of the pancreas. Non-functional Langerhan's cell tumor is usually without symptoms. The size of this tumor may reach 5–10 cm. Most sonograms show the round or oval boundary of clear hyperechogenic masses, which may appear nodular and undergo cystic changes.

(ii) Sarcoma and hemangioma of the pancreas: Ultrasonographic expressions show low-level echoes or echoless silent areas, and echoes at the posterior wall decreases. Hemangioma of the pancreas is seldom seen and its volume may reach several centimeters. Its sonogram resembles that for hemangioma of the liver (Fig. 6.24)

Fig. 6.24 Sonogram of giant hemangioma of the head of the pancreas.

6.5.5. Other Diseases of the Pancreas

(a) Stone in the pancreas.

Mainly found in the pancreatic duct, it develop mostly from chronic pancreatitis or parasites. It may be found in the main duct of the pancreas head, singly or with many others. The sonogram reveals an enlargement or constriction of the pancreas and hyperechogenic mass of enhancement of echo may be found inside it. Its posterior often has perpendicular acoustic shadows and dilatation of the posterior end of the pancreatic duct also occurs often. Inside the pancreas, the sonogram presents chronic pancreatitis with uneven echo. Small stones may not have acoustic shadows. The stones at the head of the pancreas should be differentiated from the stones at the lower end of the common bile duct. The latter has various degrees of dilatation of the common bile duct or/and is accompanied by mild dilatations of the pancreatic duct, while the former only has dilatation of the pancreatic duct (Fig. 6.25).

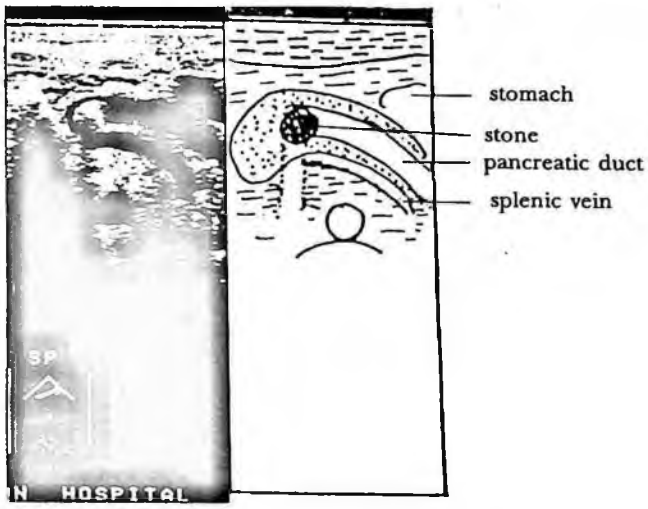

Fig. 6.25 Stone in the pancreatic duct.

(b) Parasites in the pancreatic duct.
We often find ascaris in the pancreatic duct, accompanied by ascaris in the biliary tract and pancreatitis. Inside the main duct of the pancreas, echoes of the ascaris body may be found, and the posterior end of the pancreatic duct may show dilatation.

(c) Annular pancreatic tissue.
It is a congenital deformity. Part of the pancreatic tissue surrounds the descending part of the duodenum, forming a circular narrow band. Clinically, abdominal pains, nausea and vomiting due to oppression may be experienced. The sonogram may reveal part of the circular pancreatic tissues.

Chapter 7

Ultrasonographic Diagnosis of Diseases of the Spleen

Lin Liwu

The spleen is located inside the left hypochondrium. Due to its small volume, clinical physical examination by X-ray is unable to detect the pathological changes easily. In recent years, real-time ultrasonic imaging can not only display the size of the spleen and find the lesion, it can also display the splenic blood vessels and indirectly diagnose many diseases of the liver and portal hypertension. Being able to predict the course and understand the surroundings of the spleen is useful diagnosing diseases of some whole body, such as septicemia and hematopathy.

7.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE SPLEEN

The spleen is a smooth, flat, round solid organ. It is located in the left upper abdomen below the diaphragm. Its length is about 10–12 cm, the width is about 7–8 cm, the thickness is about 3–4 cm, and its long axis is parallel to the 10th or 11th rib. The spleen has an interior and an exterior surface. The exterior surface is smooth and protruded, it is connected to the left subphrenic peritoneum. The interior surface is concave with indentation, and is found near the left kidney, stomach, the tail of the pancreas and splenic flexure of the colon. The centre of the visceral surface is the hilus of the spleen, where the splenic artery and vein go in and out. The projection of the spleen on the abdominal surface is such that the upper pole of the spleen is at the midaxillary line, approximately at the height of the 9th rib, and the lower pole is at the left anterior axillary line, at the 11th rib.

7.2. UTLRASONIC IMAGING EXAMINATION OF THE SPLEEN

7.2.1. Preparation

No special preparation is necessary for the patient. For understanding the condition of the hilus of the spleen, the tail of the pancreas and the right kidney, the patient may drink 500–800 ml of water before the examination. For differentiating the tumor around the spleen, the examination may be done after a laxative is given or after defecation. The condition of the equipment is similar to the examination of the liver.

7.2.2. Body Position and Method of Examination

7.2.2.1. *Supine Position and Coronary Section*

The patient assumes the supine position. Place the probe under the axilla and let the sound beam point to the vertebral column, parallel to the coronary section and perpendicular to the cross-section. At this moment we may get the traditional long axis of the spleen. If we move the probe laterally forward, i.e the anterior coronary section, we will get the longest diameter of the spleen (Fig. 7.1).

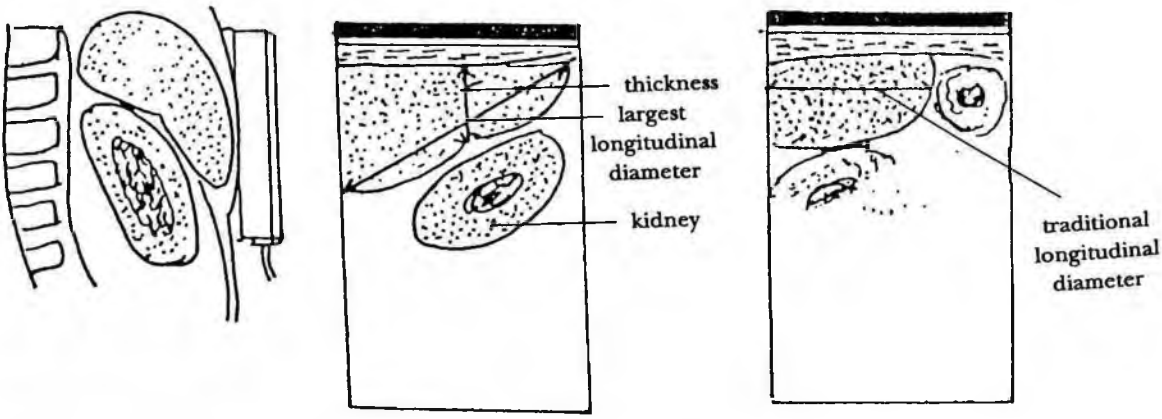

Fig. 7.1 Examination of the spleen and measurement of diameter.

7.2.2.2. *Right Decubitus Examination*

The patient is in the right decubitus position. Placing the left arm on the head can widen the intercostal space. Since the decubitus position will cause the spleen to rotate forward and descend to the hypocostal, the dilated intercostal space will facilitate the intercostal sweeping of the spleen.

7.2.2.3. *Examination by Deep Inspiration and Distention of the Abdomen*

Deep inspiration will displace the abdominal viscera, such as the liver, kidney, spleen, pancreas and gall bladder, downwards to hypocostal. This facilitates the display of these organs. By means of abdomen distention, the diaphragm constricts and the abdominal viscera is displaced to the anterior wall. The spleen may be clearly displayed.

7.2.2.4. *Examination by Other Positions*

The above-mentioned methods are routine for the examination of the spleen. When the spleen is enormously enlarged, or splenoptosis occurs, or the spleen wanders, the probe may be moved to the mid-lower abdomen and even crossing-over the median for examination. Sometimes, in order to avoid the influence of the content in the splenic flexure of the colon, the examination may be done at the posterior axillary line near the hypochondrium. But this is often combined with deep respiration to eliminate interference from the gas in the lung.

7.3. NORMAL SONOGRAM OF THE SPLEEN

The spleen is mainly composed of blood sinus and lymphatic tissues. In general, the echo is rather low. A normal sonogram echo of the spleen is similar to that of the parenchyma of the kidney or a section of the liver. The spleen has a very thin capsule. The longest diameter of the spleen in an adult is about 12 cm, and the thick diameter of the hilus of the spleen is less than 4 cm. Since the thick diameter measurements are rather constant, they therefore serve as the basis of measurement of the size of the spleen. In general, the thickness of the spleen in children is not over 2–3 cm.

7.4. ULTRASONOGRAPHIC DIAGNOSIS OF COMMON DISEASES OF THE SPLEEN

7.4.1. Splenomegaly

The enlargement of the spleen is the sign often seen. The causes are many, they are mainly: (a) infectious splenomegaly, such as acute and chronic hepatitis, spticemia, malaria and schistosomiasis; (b) hepatopathy such as leukemia and certain anemia; (c) portal hypertension due to cirrhosis of liver; (d) all causes of extravasation of the liver such as cardiac failure and obstruction of the inferior vena cava; (e) splenic tumor such as lymphsarcoma, Hodgki's Disease, cavernous hemangioma, primary or metastatic carcinoms of spleen; (f) splenic abscess and hematoma and; (g) splenic cyst including congenital, echinococcus cyst and pseudocyst. The above-mentioned types of splenomegaly may be generalized as diffusive splenomegaly and space-occupying lesion. Ultrasound diagnosis shows no special characteristics in diffusive splenomegaly, and it should be combined with clinical and other data for a comprehensive diagnosis. The majority of local and overseas

authors take splenomegaly into consideration if one of the following ultrasound findings is detected:

(i) Traditional length is over 8 cm;
(ii) The thickness at the hilus of the spleen is over 4 cm;
(iii) The longest length of the spleen is over 11 cm.

In general, splenomegaly is divided into three levels. A mild degree of enlargement is only a slight enlargement of the measured value; a moderate degree of enlargement means the volume may enlarge, reaching the costal margin; a great degree of enlargement produces oppression to the surroundings, with the volume markedly enlarged and the diaphragm elevated. In serious cases, the spleen may cross over the median abdominal line, or reach the pelvis (Figs. 7.2–7.4).

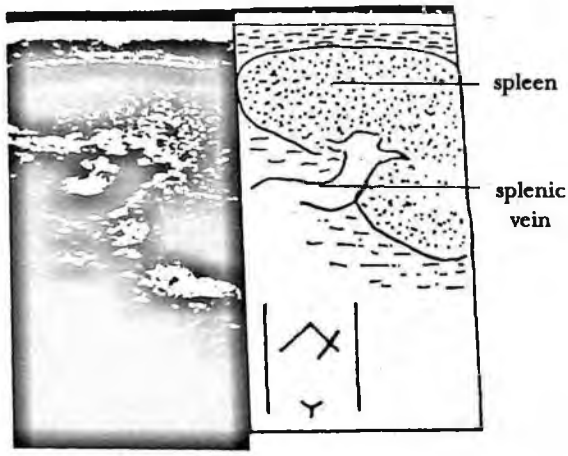

Fig. 7.2 Enlargement of the spleen, dilatation of the portal vein.

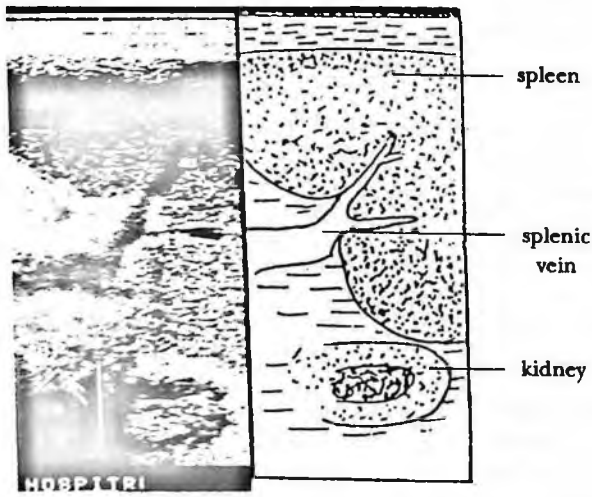

Fig. 7.3 Enlargement of the spleen at the section below the left costal margin.

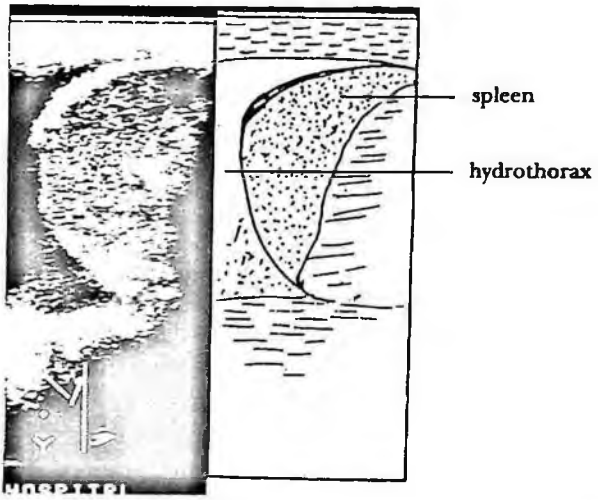

Fig. 7.4 Left intercostal space examination of the spleen when hydrothorax occurs.

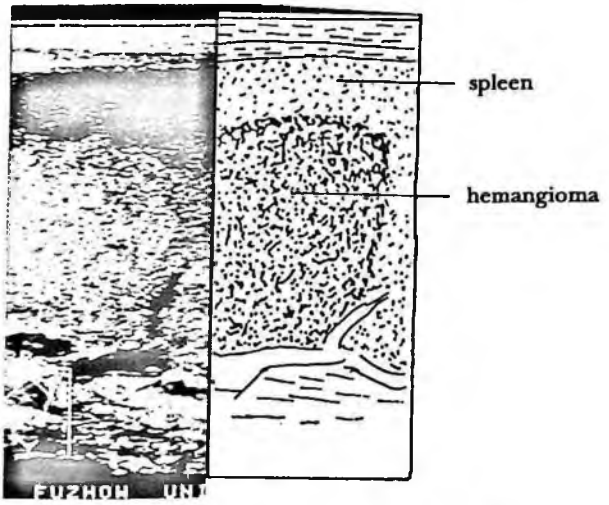

Fig. 7.5 Hemangioma in the spleen.

7.4.2. Splenic Tumor

In the past, clinical diagnosis of splenic tumors were few. Nowadays, due to the popular use of ultrasonic diagnosis, it is gradually increasing. Commonly seen splenic tumors are:

(a) Benign tumor

Benign tumors include hemangioma, hamartoma and benign cystic teratoma. Sonograms may reveal increase or decrease of the echo, or a low-level echo area in the heperechogenic area inside the spleen. The internal echo is rather homogeneous, with no sign of oppression or metastasis of the hilus of the spleen (Fig. 7.5).

(b) Malignant tumor

Lymphosarcoma and metastatic carcinoma are often seen. The ultrasound of malignant tumors reveals many low-level echo areas, an unclear, hazy or irregular boundary, or multiple nodular heperechogenic areas. Some cases may show signs of oppression due to metastasis at the hilus of the spleen. The internal echo of a tumorous mass is often uneven (Figs. 7.6–7.8).

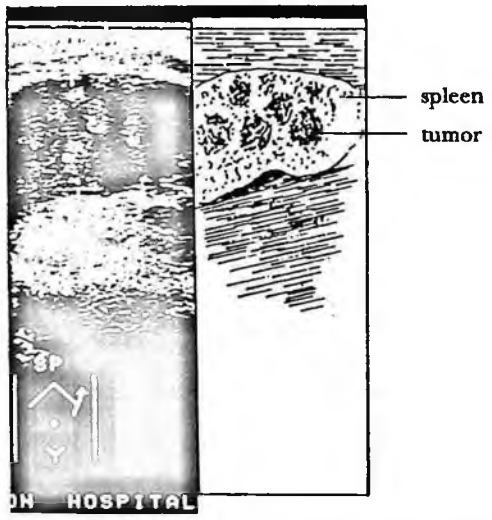

Fig. 7.6 Liver carcinoma metastatis in the spleen.

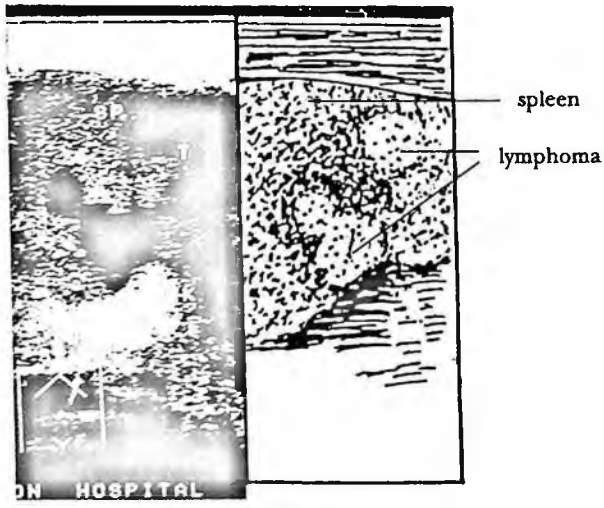

Fig. 7.7 Malignant lymphoma in the spleen.

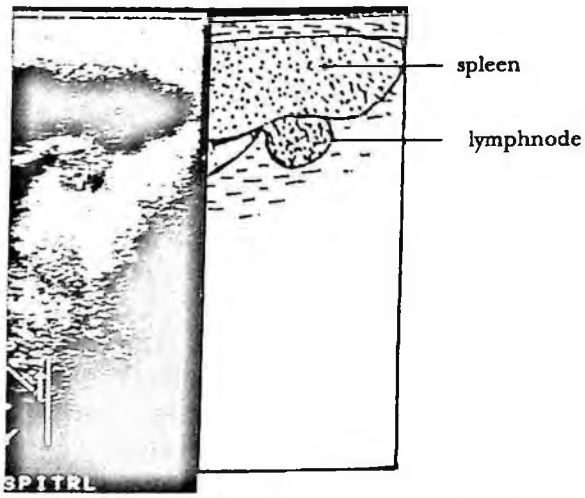

Fig. 7.8 Lymphoma with enlargement of lymph node at the hilus of the spleen.

7.4.3. Spleen Cyst

This cyst is seldom seen and may be divided into true or pseudocyst. The former is often accompanied by a cyst in another organ and its cystic wall is smooth, with good sonolucene inside the cyst. Pseudocysts include inflammatory effusion, hemorrhage and after-splenic infarction. Within the cyst are many echogenic dots or patch-like echoes formed by tissue fragments of blood cells, and the boundary morphology is also irregular.

7.4.4. Rupture of the Spleen and Subcapsular Hemorrhage

The rupture of the spleen usually results from a history of injuries. The sonogram shows loss of the complete outline of the spleen and an echoless silent area is found around the spleen. Sometimes, the echoless silent area may be far away from the spleen. Therefore, we should also use clinical methods and carefully examine the outline of the spleen. In subcapsular hemorrhage, the enlargement of the spleen occurs beneath the capsule, we may find a fluid-silent area. If the hemorrhage is serious, there may be pressure exerted on the intrasplenic tissues or they may be bulging out, but the outer margin is still smooth and the boundary remains clear. The hemorrhage may also be caused by injury and often a pseudocyst is formed. Strong echogenic dots or echogenic patches may be formed internally due to organization or calcification.

7.4.5. Abscess of the Spleen

Usually this follows after pyogenic infection in the body, with fever and pain in the splenic region. The sonogram shows the enlargement of the spleen and an echoless silent area develops internally, but its outline is not as clear as the hematoma or the cyst. Internally, echogenic dots are often seen. An abscess in the early stage appears like a honeycomb.

7.4.6. Sarcoidosis

Its sonogram shows an enlargement of the spleen and enhancement of echoes. The internal echogenic dots are markedly increase in coarseness such that they appear as small nodules. There are some signs of attentuation at the back, but there are no signs of portal hypertension.

7.4.7. Splenoptosis and Atrophy of the Spleen

Splenoptosis is usually accompanied by ptosis of the other viscera. The size of the spleen is normal. The inferior margin of the spleen exceeds the left costal margin and the position of its upper border is rather low. Atrophy of the spleen often occurs during old age or after long periods of malnutrition. With reference to this condition, the standard thickness of the hilus of the spleen is less than 2 cm and its length is less than 5 cm. Hence, at this moment, atropy of the spleen should be considered.

7.4.8. Congenital Diseases of the Spleen

Some examples are the wandering spleen and absence of the spleen. The latter occurs due to the splenic ligament being too long and it is often seen in multiparae. The position of the spleen may reach the left lower abdomen or the pelvic cavity. Some patients may develop a twisting spleen, which may be mixed up with the twisting of the ovarian cyst or pedicle of the kidney. The sonogram shows no splenic tissues in the normal splenic region. But a solid tumor similar to the spleen is examinable in the left lower abdomen or pelvic cavity, and blood vessels in the hilus of the spleen may be found. Congenital absence of the spleen means one is unable to examine the spleen in the splenic region. But the possibility of it being due to the atrophy of the spleen or a wandering spleen should already be excluded, and it should be noted whether splenectomy has been done. Besides, this condition is often accompanied by another congenital disease.

7.4.9 Sonogram of Portal Hypertension

Chronic disease of the liver, cirrhosis of the liver and other intrahepatic lesions, or compression of the branches of the portal vein raises the portal pressure such that it is the normal portal pressure of 7–10 mm Hg.

Clinical expression: enlargement of the spleen, collateral circulation and ascites.

(i) Enlargment of the spleen
About 90 to 95% of the people suffering from portal hypertension have enlarged spleens, often to a moderate or great degree. Knowing the degree of enlargement is helpful in predicting the condition (Fig. 7.9).

(ii) Dilatation of blood vessels in the portal venous system
Besides dilatation of the left and right branches of the portal vein, we may also find dilatation of the splenic vein and the superior mesenteric vein. But there are no standards for the sonograms. In general, the internal caliber of the trunk of the portal

vein is bigger than 15 mm and the internal caliber of the distal end of the splenic vein is over 8 mm. All these indicate an increase in the portal pressure (Fig. 7.10).

(iii) Collateral circulation

The commonly seen collateral circulation during portal hypertension are the opening of the umbilical vein, and the dilatation and torturous dilatation of the gastrocoronary vein and gastroesophageal vein.

(iv) Signs of ascites

Ascites are often a sign of portal hypertension in the late stages. Ultrasound is very sensitive to ascites. The positions of examination of ascites by ultrasound include the subphrenic, subhepatic (includes the gall bladder fossa and hepatorenal fossa),

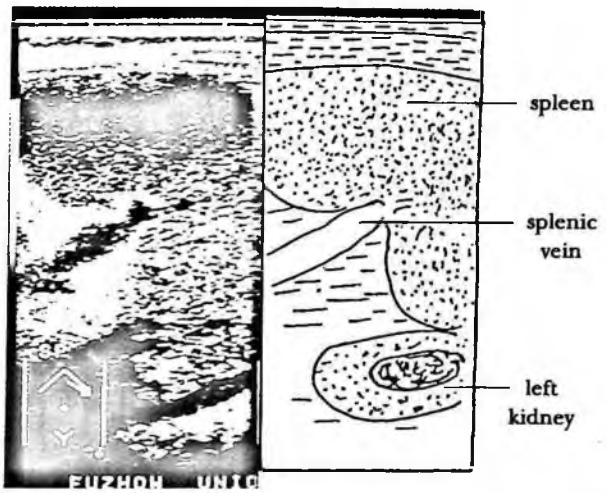

Fig. 7.9 The spleen is markedly enlarged in portal hypertension.

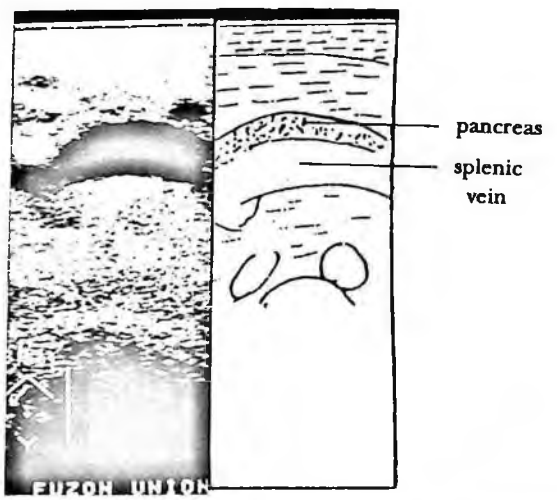

Fig. 7.10 Marked dilatation of the splenic vein in portal hypertension.

lessor omentum bursa, lateral groove of the colon, and vesicorectal fossa, etc. The subhepatic and vesicorectal fossa are the first places for the accumulation of ascites. In mild cases of ascites, silent areas with band-like fluid at the anterior hepatic space will be detected. In severe cases, ascites in silent areas around the liver or spleen may be found. The gall bladder is floating in the serous fluid in the peritoneal cavity while the intestine is floating at the highest point of the abdomen (Figs. 7.11 and 7.12). Severe cases of ascites should be differentiated from giant ovarian cysts. In the former, the intestine floats around the umbilicus or below the xyphoid; in the latter, the intestine is pushed to both sides of the abdomen. These two are easy to differentiate.

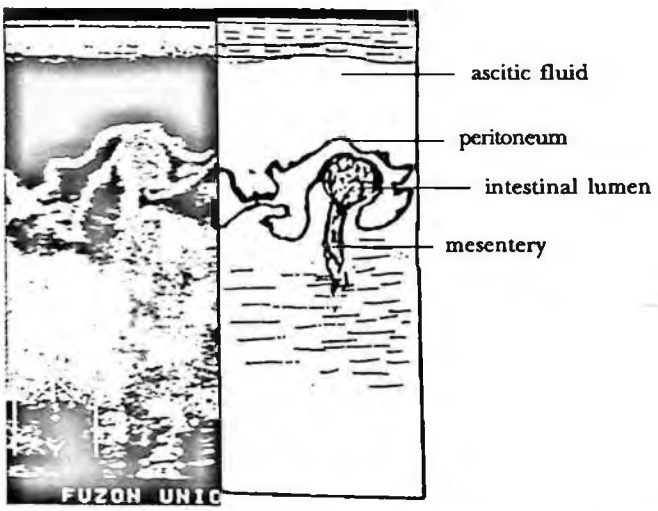

Fig. 7.11 Peritoneum, intestinal lumen and mesentery in case of ascites.

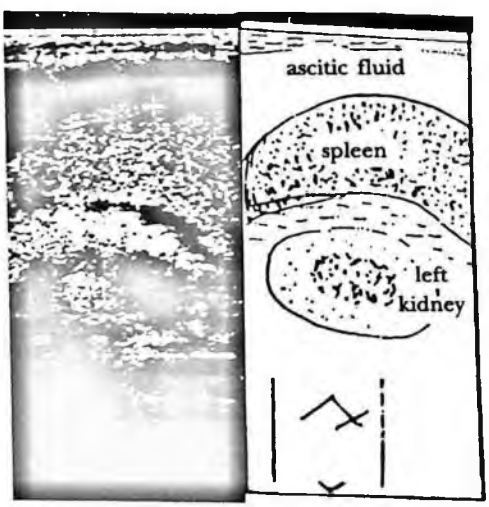

Fig. 7.12 The spleen in the case of large amount of ascitic fluid.

Chapter 8

Ultrasonic Imaging Diagnosis of Diseases of the Digestive Tract

Lin Liwu

With the continuous advance of the resolution of ultrasonic apparatus and improvements in examination techniques using ultrasound on the digestive tract, ultrasonic diagnosis of diseases of the digestive tract is gradually being respected. Many diseases, such as the tumor of the lower end of the esophagus, cardiac tumor, extra-gastrogenic tumor, intestinal tumor, adhesion, infiltration and the metastatis of the tumor of the digestive tract to the abdominal cavity and viscera, can now be understood by ultrasonography. At the same time, under real time imaging, the motility and functional condition of the digestive tract can be understood, for example, the relaxation and contraction peristalsis and the mechanism of evacuation, which cannot be revealed by X-ray examinations. Interference from the gas in the gastrointestinal tract can be improved and overcome by drinking sufficient water or by infusion of fluid. The layers making up the gastrointestinal tract can be revealed by ultrasonography and very reliable information can be obtained. Nowadays, ultrasonogram imaging, fibroscope, and X-ray barium mean examinations are used to diagnose diseases of the digestive tract, and they are also highly respected.

8.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE DIGESTIVE TRACT

8.1.1. Esophagus

The esophagus joins to the stomach. A major part of it is in the thoracic cavity above the diaphragm. Its lower segment is below the diaphragm and to its anterior is the left lobe of the liver. Its lower end is connected to the cardia of the stomach.

8.1.2. The Stomach

It is located at the upper part of the abdomen, its upper end consists of the cardia which is connected to the esophagus and its lower end has the pylorus connected with the duodenum. Its upper margin, sunken concavely, is called the lesser curvature of the stomach, while its lower margin, which bulges convexly is called the greater curvature of the stomach. The gastric wall is about 3 mm thick and comprises of layers of mucous membrane, submucous membrane, musculature, and serous membrane.

The cardia is approximately at the 9th or 10th thoracic vertebra of the spinous process. The pylorus is at the level of the 12th thoracic or 1st lumbar vertebra, which are approximately in the middle of the xyphoid-umbilical line. The right anterior wall of the stomach is covered by the liver, and the left side by the costal part of the diaphragm. The less curved part of the stomach is covered by the left lobe of the liver and the more curved part is joined to the transverse colon. A part of the anterior wall is in direct contact with the anterior abdominal wall. Its posterior wall, separated by the omentum bursa, is in contact with the pancreas, diaphragm crux, left suprarenal gland and the spleen. The stomach is divided into three parts, namely the fundus, located at left upper to the cardiac, the pylorus between the indentation of the stomach and pylorus, and the body, between the fundus and pylorus (Fig. 8.1).

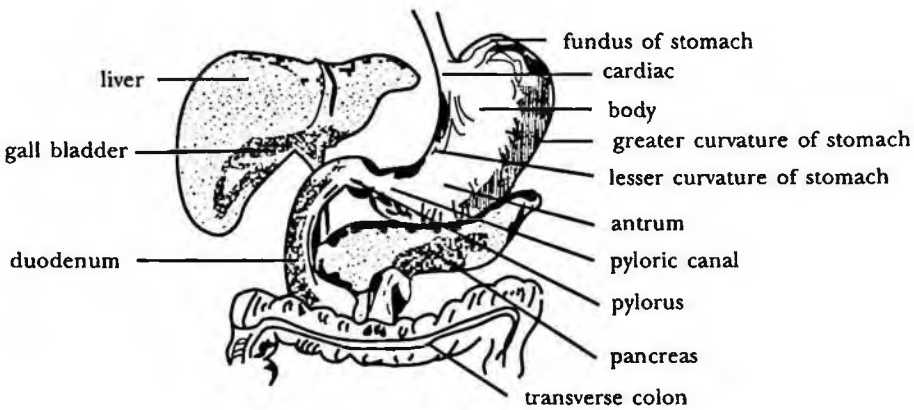

Fig. 8.1 Sketch map of the anatomy of the stomach.

8.1.3. Intestine

The small intestine is divided into the duodenum, jejunum and ileum. The duodenum joins superiorly to the pylorus of the stomach and inferiorly to the jejunum. The axis of the bulge of the duodenum, parallel to the gall bladder, is located left posterior of the gall bladder. The internal side of the descending portion is close to the head of the pancreas, while its posterior is near the right kidney and the inferior vena cava. Its horizontal portion is at the inferior of the pancreas and its ascending portion is left anterior to the abdominal aorta. The duodenum is like a horseshoe embracing the head of the pancreas. The jejunum and ileum are mesoabdominal viscera located in the hypocolonic region.

The large intestine includes the cecum, appendix, colon and rectum. The cecum and appendix are located in a right iliac fossa called the ilieocecal region. The colon is further divided into the ascending colon, transverse colon, descending colon, and sigmoid colon. The hepatic flexure of the ascending colon is next to the inferior pole of the right kidney. The transverse colon is usually at the inferior part of the stomach. The splenic flexure of the descending colon is near the spleen and left kidney. The posterior of the sigmoid colon lies on the pelvic wall and its infer-anterior is located at the bottom of the urinary bladder or the fundus of the uterus. The total length of the rectum is about 12–15 cm. In males, the anterior wall of the rectum is close to the urinary bladder after going through the vesicorectal fossa, and its inferior is adherent to the eprostate. In females, the anterior wall of the rectum is close to the uterus after going through the uterointestinal fossa, while its inferior wall is joined with the posterior wall of the vagina.

8.2. EXAMINATION OF THE DIGESTIVE TRACT BY ULTRASONIC IMAGING

8.2.1. Preparation Before Examination

In general, the linear array real-time ultrasonic imaging appratus is used. If necessary, a sector arc probe or a rectal probe is applied. The frequency of the probe is 3.5 MHz. For children and patients with thin abdominal walls, a 5-MHz probe may be used to raise the resolution. Before examination, the patient is prepared as follows:

(a) Fasting for 12 hours prior to examination, but patients in acute and critical cases are not under this restriction;
(b) Ultrasound examination of the digestive tract should be arranged prior to an X-ray barium mean flouroscopy;
(c) Examination of the large intestine should be done after thorough defecation or enema;
(d) The urinary bladder should be well-filled before the examination of the sigmoid colon and rectum.
(e) If filling the intestine with fluid is necessary, food intake should be limited or a liquid diet should be given on the day before examination. Have a laxative before sleep, defecate and cleanse the enema before the examination, then drink water to ensure the gastrointestinal tract is filled with fluid.

8.2.2. Method of Examination

8.2.2.1. *Position of the Patient*

Usually the supine, sitting or upright position is assumed and the body position is continually changed to examine the patient from different directions and sections in order to avoid the influence of gas.

8.2.2.2. *Examination of an Emptied Stomach*

Understand the overall condition and the slope of pathological change of the digestive tract.

8.2.2.3. *Examination by Drinking Water or Infusion of Water*

After the examination of the stomach, if no distinct retention of fluid in the gastrointestinal tract is observed, drinking water will help. In general, 500–800 ml of fluid is taken, increasing or decreasing the amount only when necessary. Then in the flat right anterior oblique or right decubitus position the cardiac, fundus, body of the stomach, pylorus and duodenum may be observed.

8.2.2.4. *Examination by Infusion of Water into the Large Intestine*

After cleansing the enema, the patient assumes the right decubitus position. A tube is inserted through the anus and warm normal saline is infused. Then the examination is conducted in the rectal and cecal regions.

8.2.2.5. *Examination by Means of a Rectal Probe*

It should be done after cleansing the enema.

8.2.2.6. *Items to be Observed During Ultrasonic Examination*

(a) Understanding the position, morphology, and outline margin of each part of the digestive tract;
(b) The thickness of the wall of the digestive tract, for example, the thickness of the gastric wall;
(c) Internal echoes and functional conditions such as peristalsis and the time of evacuation of the digestive tract;
(d) Location and dimension of pathological changes;
(e) The mode and positions of development of the tumor in the digestive tract, and the conditions of the surrounding viscera.

8.2.3. Examination of Each Part of the Digestive Tract and Features of the Sonogram

8.2.3.1. *Long Axial Section of the Lower End of the Esophagus*

The probe is placed on the median line of the upper abdomen, inclined towards the outer left superior direction. Sound beam passes through the left lobe of the liver as a sonolucent window, allowing the posterior margin of the left lobe of the liver to be seen. The anterior margin of the abdominal aorta shows a silent band with two parallel lines whose width, in general, is about 1 cm. Its internal echo shows a linear light strip and this represents the junction of the stomach and esophagus (Fig. 8.2).

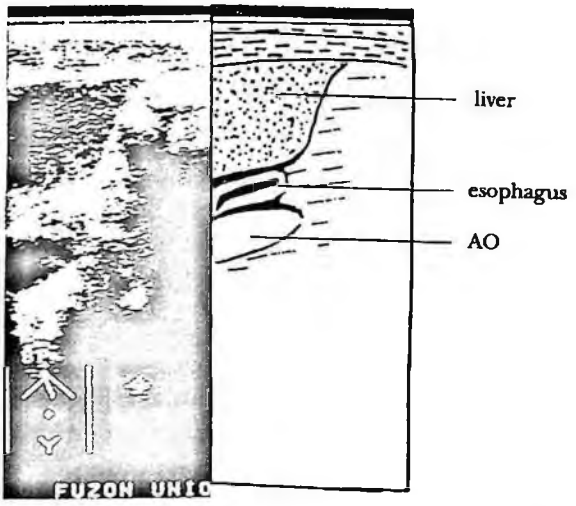

Fig. 8.2 Sonogram of the longitudinal section of the lower end of the esophagus.

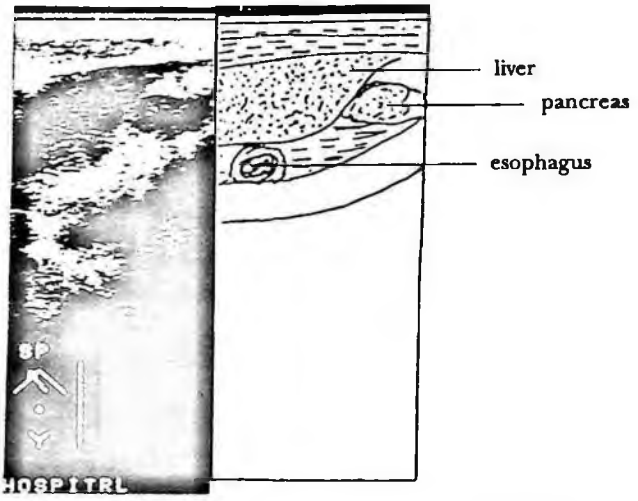

Fig. 8.3 Sonogram of the oblique section of the lower end of the esophagus.

8.2.3.2. *Short Axial Section of the Lower End of the Esophagus*

The probe is placed below the xyphoid process, inclined from the lower right to the upper left, and nearly perpendicular to the long axis plane. A target ring sign can be found between the left exterior lobe of the liver and abdominal aorta, or a little bit inclined to the left. It is at the short axial plane of the junction at the lower end of the esophagus and stomach, and its interior gas echoes may be found (Fig. 8.3). When examining the esophagus after drinking water, one may find an ultrasonograph of a water stream passing through.

8.2.3.3. *Section of the Cardiac of the Stomach*

At the longitudinal section on the paramedian of the upper abdomen, we may find its superior joined with the silent band of the esophagus. Its inferior is transitional to the internal lumen of the gastric wall. Here, it abruptly widens like the bell of a trumpet. When drinking water or swallowing, we may find movement of the fluid or enhancement of echogenic dots.

8.2.3.4. *Section of the Fundus of the Stomach or a High Level of the Stomach Body*

Placing the probe on the left costal margin, the sonogram reveals an oval-shaped image containing fluid at the inferior visceral surface of the left exterior lobe of the liver. Its morphology varies with the amount of water and within different individuals. Its anterior wall joins the liver, and the external posterior wall of the fundus joins to the spleen. Posterior to the body of the stomach are the body of the pancreas and the left kidney. After filling, the thickness of the gastric wall is 3–5 mm, nearly identical to the measurement by X-ray. The thickness of the gastric wall is related to the filling.

8.2.3.5. *Section of the Gastric Antrum and Body of the Stomach*

Mostly, the patient assumes the sitting or upright position. The probe is placed on the upper abdomen, below the xyphoid forming many sections, in order to understand the body, the antrum and the other parts. The sonogram varies with different stomach shapes, for example, a horn-shaped stomach has to be placed transversely. In the image, the separation of the antrum and body is not distinct. In an asthenic stomach, the body and antrum are narrow and the corner of the stomach is usually below the level of the umbilicus (Fig. 8.4). Due to the presence of the pyloric sphincter and its thickness, which is less than 7 mm in general, the degree of filling is not greatly affected.

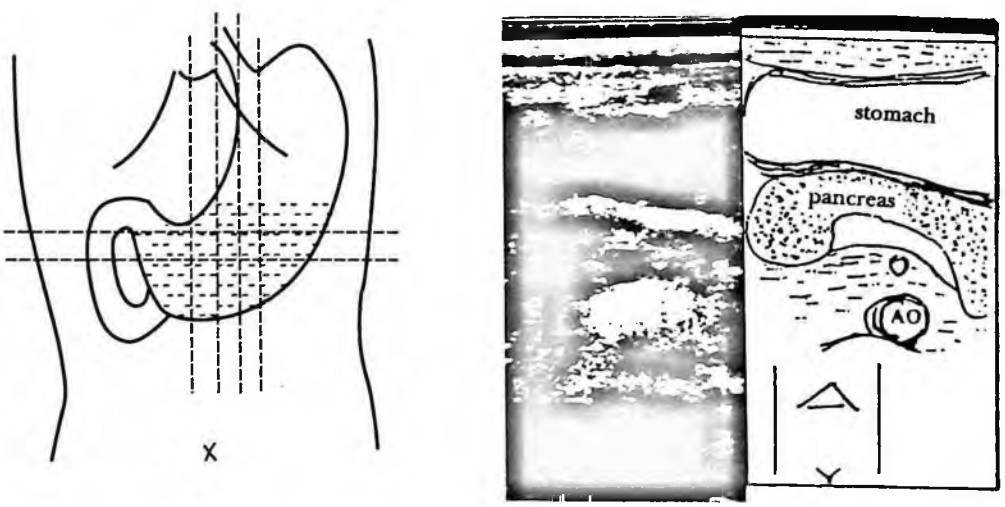

Fig. 8.4 Sectional drawing of the antrum and body of the stomach. Left diagram: sectional sketch map of the stomach; right diagram: sonogram of the horizontal section of the antrum and body of the stomach .

8.2.3.6. *Section of the Duodenum*

The examination of the right costal margin at the upper abdomen shows the bulge is at the inferior of the left internal lobe of the liver and at the internal inferior of the gall bladder. Parallel to the long axis of the gall bladder, one may find the fluid fully-filled with floating minute echogenic dots. The descending portion is at the lateral side of the pancreas head and the horizontal portion is at the inferior. The ascending portion is not clearly displayed.

8.2.3.7. *Section of the Jejunum and Ileum*

There is no distinct demarcation between these two. A greater part of the jejunum is in the left upper abdomen and middle lower abdomen, while the ileum is in the right lower and middle lower abdomen. In general, the section is not clearly displayed, except when it is in ascitic fluid, where it presents mushroom-like structures.

8.2.3.8. *Section of the Large Intestine*

In general, it is not easily displayed except when there is an obvious blockage in the low levels of the intestine, during which we may find the large intestine presenting big bead-like channels containing fluid. The rectum may be found behind the fully-filled urinary bladder, or the female uterus.

8.3. NORMAL SONOGRAM OF THE DIGESTIVE TRACT

Inside the digestive tract, there are gases, liquids, and all kinds of chymes and faeces, so the sonogram is very complicated and varies greatly. But it is also due to the movement and changes of the above-mentioned contents that allows us to understand the condition of the wall and lumen of the digestive tract. A normal sonogram of the lower end of the esophagus shows a band-like strip or alternating target-like dark rings. Its interior has gaseous echogenic dots and its exterior is embraced by a linear solid silent area. The morphology of the stomach varies with the filling state and the position of the sections. The location of the cardiac is rather constant and it forms an oval shape. It is surrounded by linear echoes created by the membranous layer; its centre consists mainly of low-level echoes formed by the muscular layer. The strong echoes formed by the mucous membrane and lumen is in the middle of the low-level echo area. Apparatus with a high resolution may be used to divide the gastric wall into five layers: the first and the second layers mainly represent the muscous layer and mucomuscular layer, the third layer shows strong echoes in the submucous, the fourth layer represents the muscular layer expressing low-level echoes, and the fifth layer is the serous membrane layer and interface of surrounding tissues expressing strong echoes. In general, ultrasound mostly reveals three layers of construction: the mucous membrane and submucous membrane express strong echo, the middle layer has low-level echoes of the muscular layer and the outer serous membrane layer expresses strong echoes. The thickness

of a normal gastric wall is about 3–5 mm, and the thickness of pylorus is generally not over 6–7 mm.

The normal intestinal wall is not easily displayed. It may be displayed after being filled with liquid. It has linear strong echoes, and its thickness, in general, is between 2–3 mm.

In real-time images, gastrointestinal peristaltic waves can be found. The peristaltic wave of the stomach starts from the fundus and moves to the pylorus, presenting a small mould bulging to not greater than 1 cm in height. It is considered normal if 1–2 peristaltic waves appear in the image of a 10 cm-long probe. If a peristaltic wave bulges too high or too frequently, it is known as hyperperistalsis. If the movement is in the opposite direction, it is known as reverse peristalsis. Normal emptying of the stomach after drinking 500 ml of water is 60% in the first hour, and in the second hour the emptying has been practically completed. Otherwise, various degrees of pyloric obstructions will have to be considered.

8.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE DIGESTIVE TRACT

8.4.1. Ultrasonic Analysis of the Lesion of the Digestive Tract

8.4.1.1. *Abnormal Construction of the Tubular Wall*

It is an essential basis for the diagnosis of lesions of the digestive tract. It shows by the destruction or disappearance of the construction of the tubular wall's normal layer, causing it to appear localized or diffusively-thickened. If the tubular wall is 2–3 times thicker than normal, this condition is called marked thickening.

8.4.1.2. *Appearance of Abnormal Parenchymal or a Mixed Tumor*

Various signs can develop due to the different locations and degree of a lesion. Localized thickening occuring in the tubular wall forming a crescent or a ring shape, or marked thickening causing constriction of the tubular lumen and forming a horseshoe sign, targeting sign, or pseudo kidney sign, are mostly signs of tumor. There may be a double hump sign, which is a sign of ulcer.

8.4.1.3. *Abnormal Internal Echo*

Echoes in the tubular wall of the lesion area are abnormal, and there is loss of the original internal and external strong echo lines and a low-level echo band in the middle. According to the nature of the lesion, there may be a variation of strong or low-level echoes.

8.4.1.4. *Abnormal Functions*

Hyperperistalsis, hypoperistalsis, disappearance of peristalsis, retention of fluid or regurgitation due to evacuation are all abnormal functions.

8.4.2. Sonogram of Common Diseases of the Digestive Tract

8.4.2.1. *Carcinoma of the Esophagus*

This refers mainly to carcinoma of the lower end of the esophagus. A sonogram shows localised thickness of the tubular wall, irregular margin deviated or torturous strong echogenic dots in the middle. Observations made when drinking water may show a change in the line fluid flow or the line becomes thinner due to blockages (Fig. 8.5).

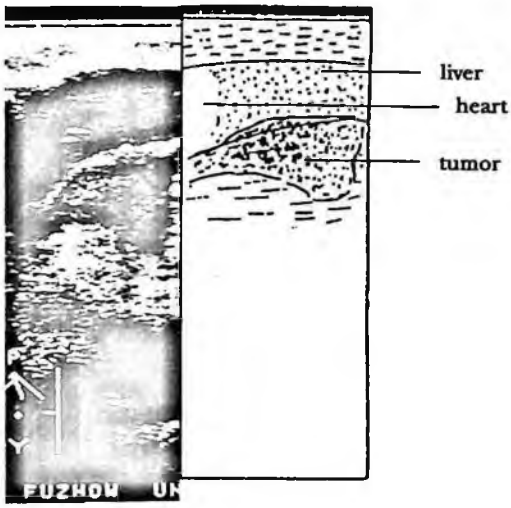

Fig. 8.5 Sonogram of a tumor at the lower end of the esophagus.

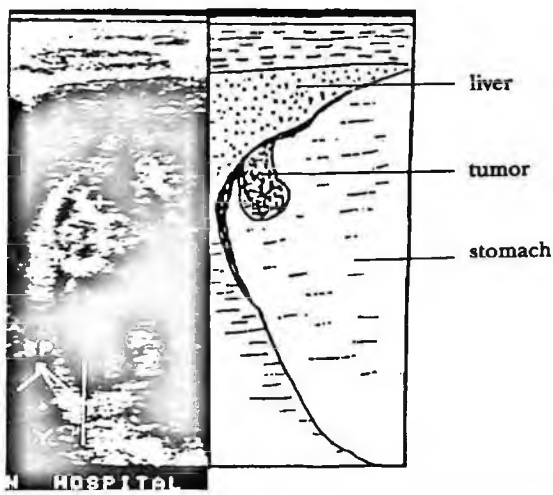

Fig. 8.6 Tumor in the cardiac of the stomach (examined after drinking water).

8.4.2.2. *Carcinoma of the Cardiac of the Stomach*

The sonogram shows an enlargement and irregularity of the silent area in the cardiac, and deviation of the echogenic dots in the lumen. The distance between the posterior margin of the left lobe of the liver and the anterior margin of the abdominal aorta is widened. The volume of the tumor is rather big and may protrude into the lumen or protrude outward, causing the direction of the fluid flow to be changed when drinking water (Fig. 8.6).

8.4.2.3. *Tumor in the Stomach*

The most commonly seen is carcinoma of the stomach. Its sonogram expressions vary with the location of development, invasion and metastatsis, and different stage of the condition:

(a) Thickening of the gastric wall
It is mostly seen in the early stages of carcinoma. Localized thickness gives low-level echoes. These should be differentiated from those due to peristaltic waves. Peristaltic waves are not constant, but the thickened gastric wall means the same even after a change of body position. Since the area of lesion is small, it should be combined with other examinations for a more accurate diagnosis.

(b) Infiltrative lesion of the gastric wall
It may be divided into local infiltration and diffusive infiltration. Its sonogram shows irregular thickness of the gastric wall, which bulges like a step ladder. The demarcation between the tumor and the normal gastric wall is still clear. If diffusive infiltration occurs, the gastric wall undergoes extensive uneven thickening, the gastric lumen narrows and peristalsis weakens or disappears (Figs. 8.7 and 8.8).

(c) Solid mass in the gastric wall
This is a rather typical type of carcinoma of the stomach. According to its mode of development, it may be divided into an intralumen protuberent type growth, extralumen

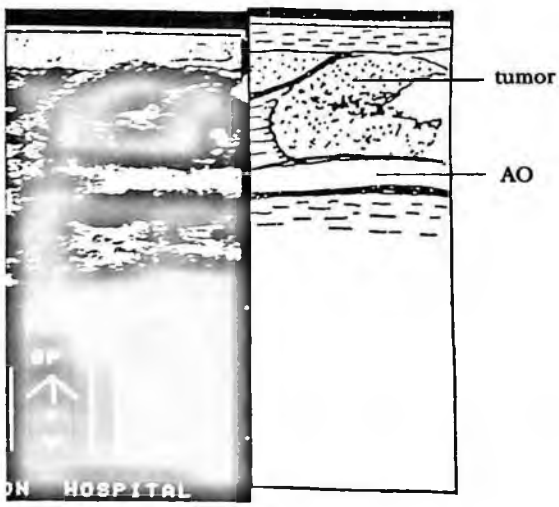

Fig. 8.7 Tumor in the antrum of the stomach forms a "pseudo kidney sign".

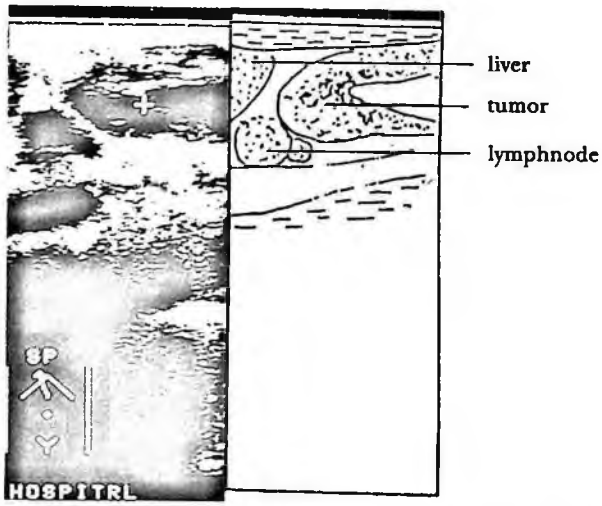

Fig. 8.8 Stomach tumor at the pylorus (diffusive), accompanied by lymph node metastasis.

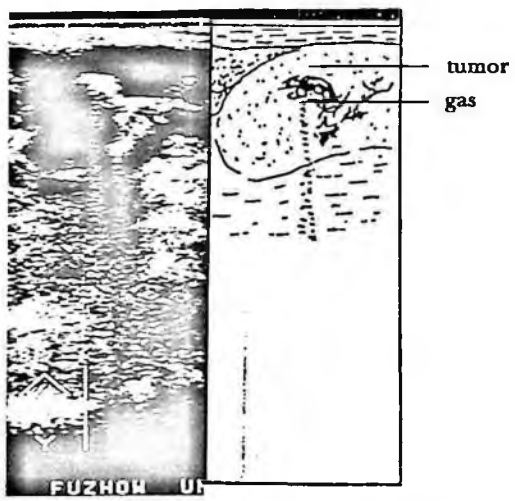

Fig. 8.9 Stomach tumor forms a "pseudo kidney sign".

outward protruding type growth, and mixed-type. Most masses give low-level echoes which are irregular or cauliflower-like (Fig. 8.9).

(d) Signs of infiltration or metastasis to the surrounding viscera

It may directly infiltrate the nearby organs such as the liver and pancreas, causing interruption to the boundary echo of these organs. A lesion may invade or metastasize into the viscera, or to the surrounding lymph nodes, including the mesenteric lymph nodes and paraabdominal aorta lymph nodes. It may also metastasize to the peritoneum, inducing ascites, or undergo long-distance metastasis to places such as the pelvic cavity, thereby appearing as a metastasized focus in the prerectal space (Fig. 8.10).

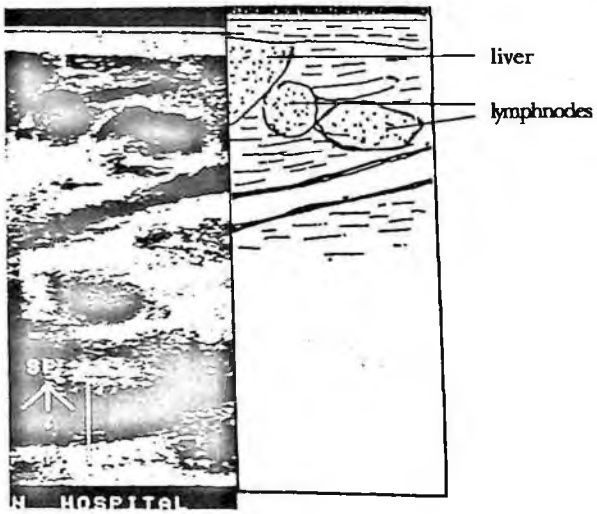

Fig. 8.10 Stomach tumor metastasized to the surrounding lymph nodes.

Other malignant tumors in the stomach, like lymphoma of the gastric wall, mostly form nodular silent areas, with few echogenic dots. There are a few benign tumors in the stomach, such as an adenoma which presents polypoid changes and protrudes into the gastric lumen. Its surface is smooth with or without a pedicle. Others such as leiomyoma, lipoma, fibroma, and hemangioma, have rather clear-cut outlines and even internal echoes. An X-ray barium meal and gastroscope examination will help make the diagnosis accurate.

8.4.2.4. *Tumor in the Intestinal Tract*

The mode of development varies. It may show diffusive, circular infiltrative development along the tubular wall, and also a mass growing within or outside the intestinal lumen. The former's sonogram shows the "target ring sign," with strong central echoes and low-level echoes, or the "pseudo kidney sign," which is long and oval in shape. If the latter grows into the lumen, we may find strong echo deviating to one side and irregular low-level echoes. If it grows outside the lumen, a lobular low-level echo area often forms. An accurate localization of a tumor in the intestinal tract is rather difficult. A tumor in the small intestine is generally accompanied with signs of obstruction such as the dilatation of the upper segment of the intestinal tract, and reverse fluid flow. Tumors in the large intestine are often seen as the "target ring sign" and "pseudo kidney sign". The location of the tumor in the rectum is rather constant, i.e. posterior to the urinary bladder or uterus (Figs. 8.11–8.15).

8.4.2.5. *Thickening of the Tubular Wall Caused by Other Diseases of the Gastrointestinal Tract*

Gigantic hypertrophy of the muscous membrane of the stomach is commonly seen. Its cause is hyperplasia of the mucous gland of the stomach, which results in marked thickening of the gastric wall. A lesion is usually located in the fundus or the body, but the antrum is generally not involved. The sonogram of the above-mentioned disease shows even diffusive thickening

of the gastric wall of the fundus and body, and the bulging of the surface of the mucous membrane like small mounds, but the muscular layer is not involved. Other commonly seen diseases are gastrointestinal tract inflammation, tuberculosis and eosinogranuloma. All of the above-mentioned diseases may appear as changes in the wall thickness, which is similar to a tumor.

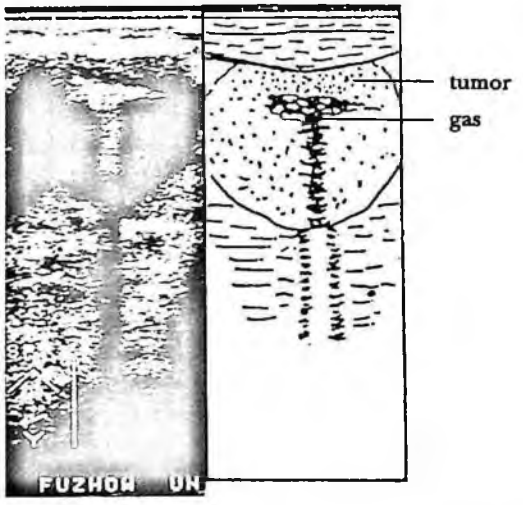

Fig. 8.11 Tumor in the intestinal tract forms a "target ring sign".

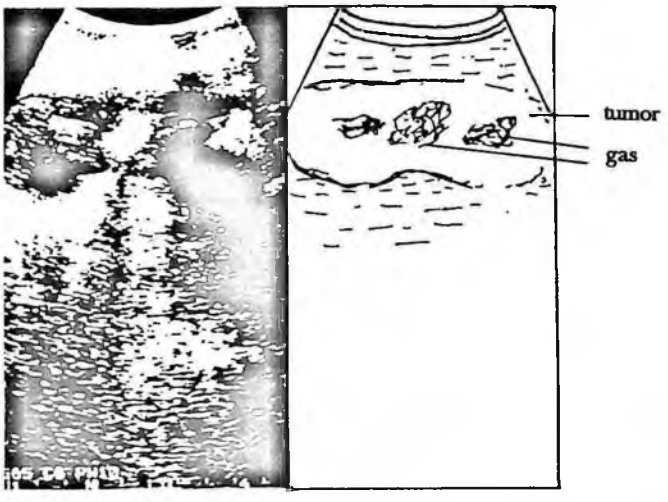

Fig. 8.12 Tumor in the intestinal tract forms a "pseudo kidney sign".

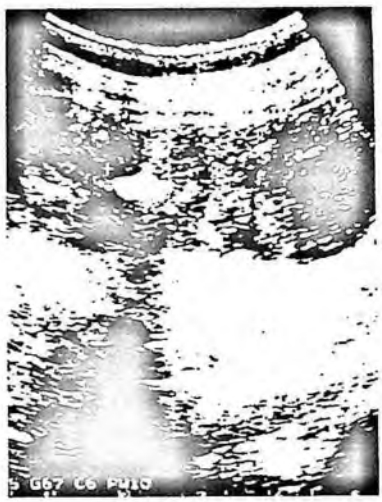

Fig. 8.13 Tumor in the intestinal tract grows into the intestinal cavity. The hyperecho deviates to one side.

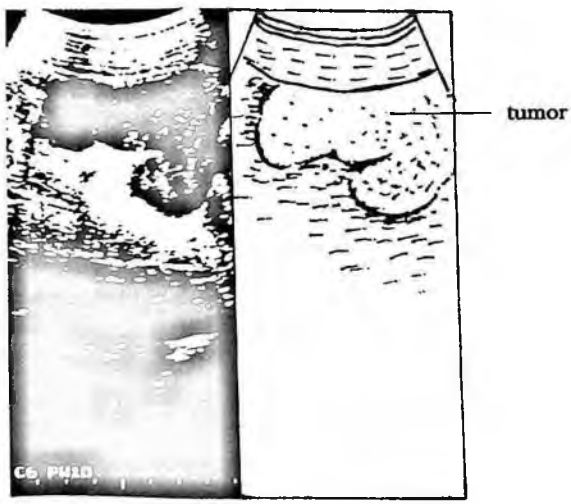

Fig. 8.14 Tumor in the intestinal tract grows out of the intestinal cavity, forming a lobulated hypoecho.

8.4.2.6. *Congenital Hypertropic Stenosis of the Pylorus*

Often seen in infants, the clinical expression of this condition is stomach retention with severe vomiting. Pathological findings show severe hypertrophy of the pylorus muscle, causing stenosis of the pyloric channel and delay in the evacuation of the stomach, resulting in retention. The sonogram shows thickening of the entire circumference of the pyloric wall with its thickness reaching to about 0.6–1.0 cm, a low-level echo ring, a markedly narrowed tubular lumen and signs of retention of the stomach contents.

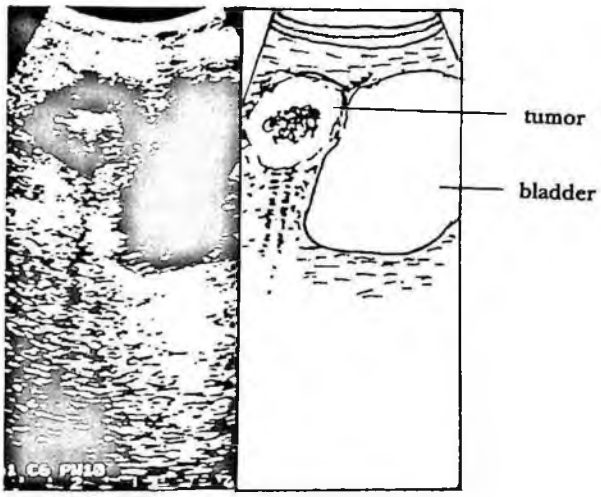

Fig. 8.15 Tumor of the sigmoid colon is usually detected at the upper end of the urinary bladder, forming a "target ring sign".

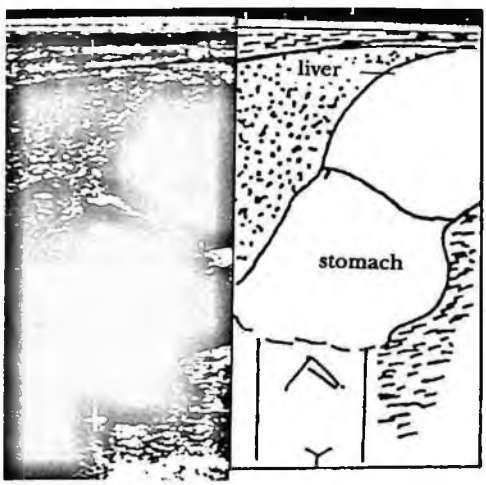

Fig. 8.16 Sonogram of an acute dilation of the stomach.

8.4.2.7. *Pyloric Obstruction and Retention of the Stomach*

The above-mentioned conditions are due to the occurence of pyloric stenosis caused by a tumor of the antrum, pylorus or peptic ulcer. Its sonogram may show a constriction or disappearance of the pyloric lumen, hyperperistalsis of the stomach, reversed peristalsis and large amount of fluid retention in the stomach. The emptying by the stomach is markedly delayed. After fasting for 12 hours, a large amount of the contents is still found in the stomach. Sometimes, we may find changes in the sonographic image of the tumor.

8.4.2.8. *Acute Dilatation of the Stomach*

The sonogram shows that the volume of the stomach is markedly enlarged. The gastric wall becomes thinner, there are a lot of gastric contents represented by the fluid-silent area, mixed with strong echogenic dots from food residues and gas. At this moment, the gastric peristaltic waves are weakened or have disappeared. The boundary of the gastric cavity may extend to the pelvic cavity (Fig. 8.16).

8.4.2.9. *Intestinal Obstruction*

Clinically, it is not uncommon to see intestinal obstruction. The causes are the presence of tumors, ascaris, intussusception or paralytic intestinal obstruction induced by peritonitis. The sonogram reveals the following:

(a) Dilatation or marked dilatation of the intestine above the location of obstruction. The intestine is filled with fluid, and we may also find flowing of fluid and movement of gas forming a fluid-fluid level or fluid-gas level.
(b) Enlargement of the intestine, forming polycystic expression. The folding of the intestinal loop may also be found (Fig. 8.17).
(c) Tumors, ascaris, and other causes of obstruction (Fig. 8.18).

8.4.2.10. *Perforation of the Stomach and Intestine*

The stomach and intestinal gas enter the abdominal cavity from the gastrointestinal tract, resulting in free gas in the abdominal cavity. Once the sonogram image displays the existence of the gas-fluid level in the abdominal cavity, a lesion or perforation is ascertained, but its definite position cannot be diagnosed by ultrasonic examination.

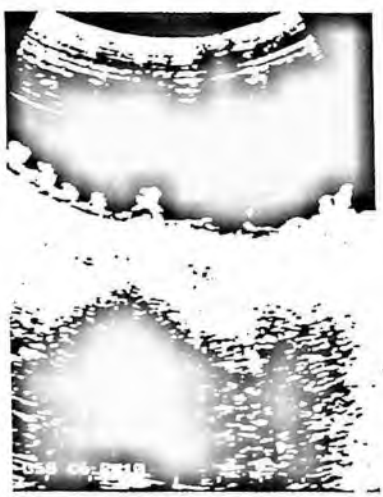

Fig. 8.17 During intestinal obstruction, the intestinal tract expands and folding of the intestinal loop can be seen.

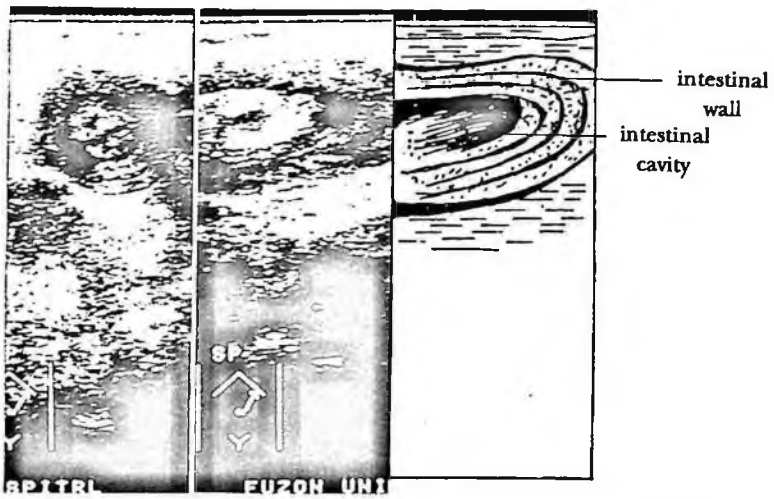

Fig. 8.18 Intussusception causes intestinal obstruction. The intestinal wall becomes folded.

8.4.2.11. *Stones and Foreign Bodies in the Stomach*

A patient with such conditions is likely to have a history of taking persimmon, black dates etc. The sonogram displays an echogenic round area in the gastric cavity. Its morphology is stable and moves with changes in the body position. There is a marked perpendicular sound shadow at its bank. If the stone passes into the intestinal tract, an obstruction often results. A foreign body in the stomach varies in its morphology and property, it mostly presents strong echoes and moves with changes in body position.

8.4.2.12. *The Change of Gastroenteritis*

(a) Gastritis

It is a common clinical condition. It is pathologically expressed as an edema of the mucous membrane of the stomach, thickening or atrophy of the gastric wall. It cannot be easily or accurately diagnosed by sonogram. The main signs are: (i) diffusive thickening of emptied gastric wall, with even low level-echo, (ii) decrease in the thickness of the gastric wall after drinking water. With high resolution rate of ultrasound, there is no thickening of the muscular layer seen, and (iii) often normal gastral peristalsis and evacuation. Ultrasonic diagnosis for gastritis is only for reference.

(b) Appendicitis

Simple appendicitis is not easily diagnosed by ultrasound. Purulent appendicitis may display appendical mass with a low-level echo, but the boundary is still clear. The appearance of an echoless dark area indicates the formation of abscesses. The sonogram for gangrenous appendicitis displays marked swelling of the appendix, showing an encapsulated mass with a liquified dark area inside and strong echogenic dots or patches of necrotic tissues. If irregular echoless or low-level echoes appears in the ileocecal region, it mostly represents the periappendiceal abscess which is displayed by the sonogram, but it should be differentiated from adnexitis or twisting of the pedicle of the

ovarian cyst. However, the position of adnexitis or the twisting pedicle is usually shifted towards the median position and is linked with the uterine angle. Diagnosis is done together with clinical observation (Fig. 8.19).

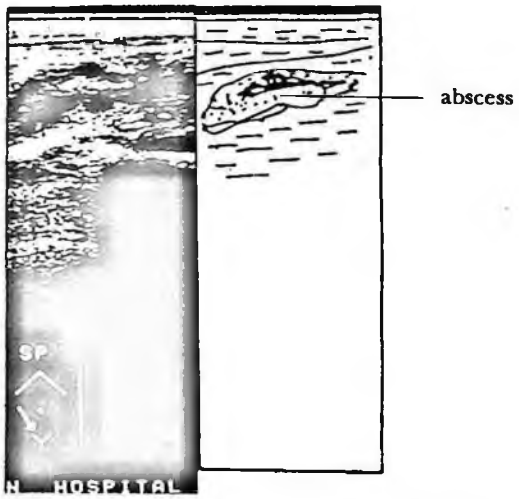

Fig. 8.19 Abscess surrounding the appendix.

8.5. DIAGNOSIS BY TRANSRECTAL ENDOSCOPIC ULTRASONOGRAPHY

Recently, transrectal endoscopic ultrasonography has been widely used for the diagnosis of diseases around the rectum and anus. It can be used to define the location of a rectal tumor, the stage of lesion, the metastasis of lymph nodes and the relation between the rectal tumor and the surrounding organs. It is also used for follow-up examinations after resection of the rectal tumor in order to detect tumor recurrence. Transrectal ultrasonography plays an important role in the evaluation of differential diagnosis of a rectal tumor from other rectal lesions.

8.5.1. Preparations Before Examination and the Method of Examination

We use the transrectal ultrasound probe (circular, linear array, sector, or mixed type) with a frequency of 5–7.5 MHz for examination. The patient fasts for 12 hours before the examination (except for emergency cases) and defecates thoroughly before the examination. After cleansing with enema, the image will be clearer.

During the examination, the probe is capped with a thin rubber cap which is lubricated with oil and the patient is asked to relax. The probe is inserted into the anus slowly. It is gradually rotated forwards, not too fast or with too much force in order to avoid tensing the anal sphincter, otherwise the probe cannot enter the rectum easily resulting in an examination failure. The author has done transrectal ultrasonography in 550 cases, with the success rate reaching 92%. During the examination, a multiple–direction examination can be

conducted according to an anal digital examination or the position of the lesion displayed by the sigmoidscope. 50–60 cc of water is put into the rubber cap to improve the sonolucent area.

8.5.2. Items for Observation:

(a) The morphology of the rectal wall and the surrounding viscera,
(b) Laminated structure and thickness of the rectal wall,
(c) Location of the rectal tumor and the range of the lesion, and
(d) The involvement of the surrounding lymph nodes and pelvic viscera.

8.5.2.1. *Sonogram of a Normal Rectum*

A normal rectal wall may have 5 structural layers, but some authors consider it to have 7. The sonogram shows that the surface of the intestinal wall is smooth, the structure of every layer is clear, and the thickness of the intestinal wall is between 0.3–0.5 cm (Fig. 8.20).

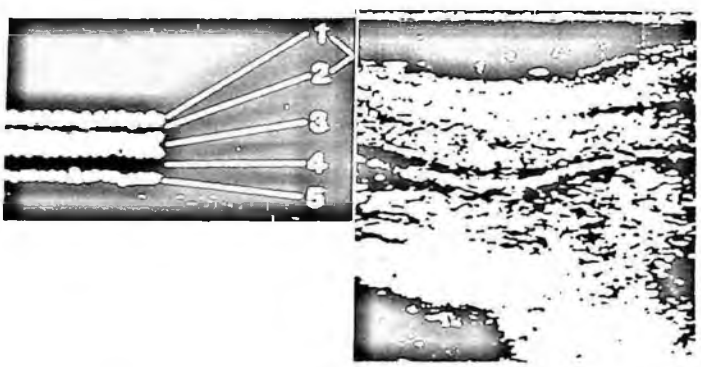

Fig. 8.20 The sketch map (left) and sonogram (right) of a normal rectal wall.
1 — mucous membrane layer
2 — mucous layer and mucomuscular layer
3 — submucous membrane layer
4 — muscular layer
5 — serous membrane layer and soft tissue

8.5.2.2. *Sonogram of a Rectal Tumor*

Expressions of the rectal tumor varies with the degree and range of the lesion. If the tumor is only growing in the mucous membrane layer, the tumor is seen as a mass or a cauliflower protruding into the intestinal cavity in the sonogram, with integral continuity of echos in the submucous membrane layer (Fig. 8.21). If the tumor invades the submucous membrane layer, the echo of this layer will not be clear and experience interruptions (Fig. 8.22). If the tumor is growing continuously into the muscular layer or outwardly invading the surrounding soft tissue, corresponding sonograms will be displayed (Fig. 8.23). Lymph nodes around the

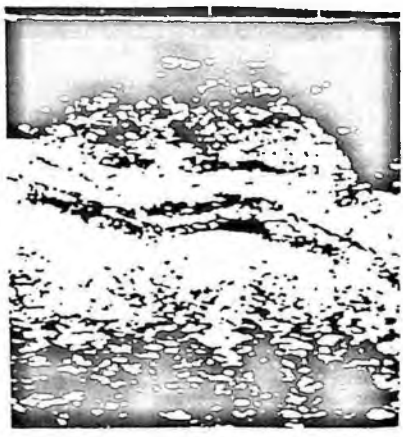

Fig. 8.21 Rectal tumor confined in the mucous membrane layer. The continuity of strong echo of submucous membrane layer is integral.

Fig. 8.22 A rectal tumor invades the submucous membrane layer. The continuity of strong echo of this layer is interrupted (right end) and normal intestinal wall (left end).

normal intestinal wall are often not displayed. If round lymph nodes with low-level echoes are seen outside the intestinal wall, it mostly indicates metastasis of the lymph nodes from the rectal tumor (Fig. 8.24). By this time, it should be differentiated from the cross-section of the blood vessel. To be sure, the scanning direction and angle should be changed. If the tumor metastasizes to the pelvic viscera, a corresponding sonogram can be seen (Figs. 8.25 and 8.26).

8.5.2.3. *Sonogram of Other Rectal and Perianal Lesions*

A sonogram of a perianal abscess: the acute perianal abscess is often diagnosed by clinical expressions and anal digital examination. Transrectal ultrasonography is not often used due to the severe pains caused. During the ultrasonic examination of chronic perianal abscesses,

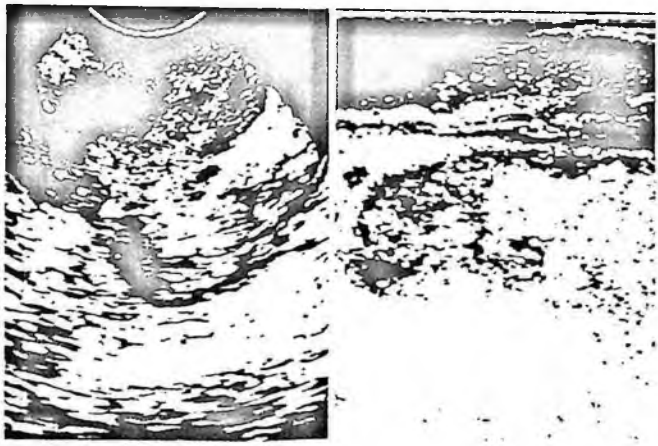

Fig. 8.23 Rectal tumor invades the muscular layer and protrudes out of the muscular layer (left figure); the tumor is growing into the soft tissue around it (right figure).

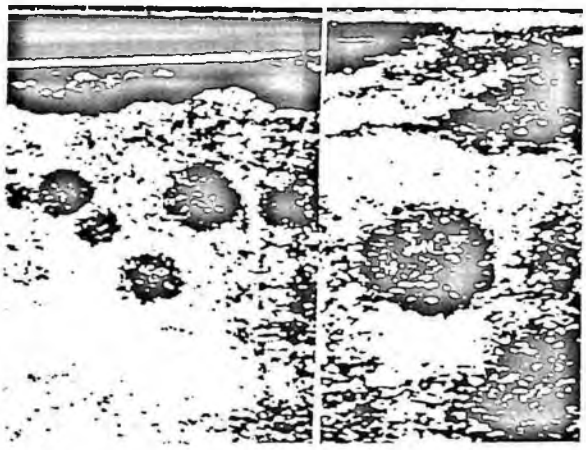

Fig. 8.24 Rectal tumor metatasizes to the lymh nodes around it.

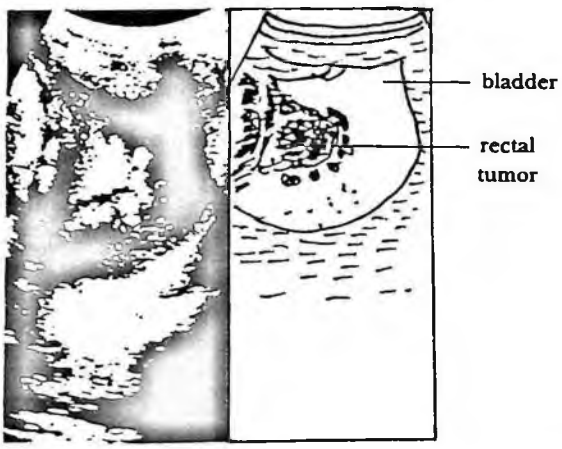

Fig. 8.25 Rectal tumor invades the urinary bladder; gas echo and fecal residual echo can be found within the urinary bladder.

Fig. 8.26 Rectal tumor metastasizes to the prostatic gland.

Fig. 8.27 Perianal chronic abscess.

everything should be done with care. Localized irregular low-level echo areas aound the anus can be seen in the sonogram, and the abscess fluid can be displayed. Strong echogenic dots can be seen within the dark area, and sometimes we may also find a sonogram of a fistula due to the presence of a chronic abscess (Fig. 8.27).

A cyst in the submucous membrane of rectum: the author found three cases in which it was clinically a rectal tumor, but transrectal ultrasonography showed it to be a cyst in the submucous membrane of the rectum. The sonogram displayed disintegration of the echo found in the submucous membrane layer, with an echoless dark area inside. The structure of the other rectal layers were clear and could be differentiated from the tumor (Fig. 8.28).

Fig. 8.28 Cyst in the submucous membrane of the rectum.

Tumors outside the rectum: some tumors grow outside the rectal wall. Due to the enlargement of the tumor, it presses against the intestinal wall, hence clinically, it is often misdiagnosed as a rectal tumor. Diagnosis by transrectal ultrasonography show the structure of the intestinal wall to be clear and complete, and can be diagnosed. The author previously found tumors outside the rectum, for example, aneurysm, lymphoma and tumor of the soft tissues (Figs. 8.29 and 8.30).

Fig. 8.29 Aneurysm around the rectum. Doppler ultrasound display pulsed message.

Fig. 8.30 Giant soft tissue tumor behind the posterior wall of the rectum.

Chapter 9

Ultrasonic Imaging Diagnosis of Diseases of the Kidneys

Lin Liwu

The anatomic position and structure of the kidneys are favourable for ultrasonic imaging diagnosis. It can directly reveal each part of the kidney without causing any trauma. It can also show the structure and pathological changes of the kidneys such as renal tumor, stone, tuberculosis, cyst, etc. without the use of any auxillary drugs. It can overcome the limitations in the applicaton of X-ray and isotope, particularly when the lower urinary tract is obstructed and the function of kidney is seriously damaged such that endoscope or intravenous contrast examination cannot be performed. The ultrasonic examination appears to be much more important. It has the following values:

(a) Early diagnosis of renal tumors;
(b) Differentiation and definition of the renal space-occupying lesions;
(c) Diagnosis of all types of renal diseases and definition of their relationships with the surrounding organs;
(d) Ultrasonically-guided puncture to perform pyelograph or cytological and histological examinations;
(e) The observation and monitoring of a transplanted kidney.

9.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE KIDNEYS

The kidneys are a paired, parenchymal retroperitoneal viscera, located on both sides of the vertebral column on the psors major muscles. Its posterior is in close contact with the quadratus lumborum. The kidneys are found below the diaphragm, approximately between the 11th thoracic and the 3rd lumbar vertebra. The right kidney is lower than the left kidney by about half of a lumbar vertebral body. For it's nearby relations, see Figs. 9.1 and 9.2. The external lateral margin of the kidney is convex, its internal lateral margin is concave. The

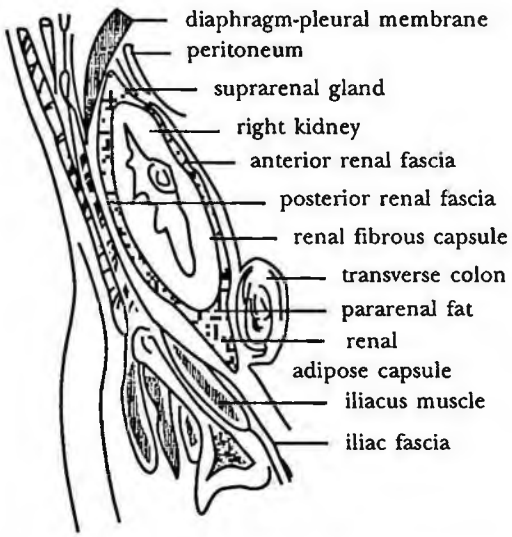

Fig. 9.1 Anatomic position of the kidney.

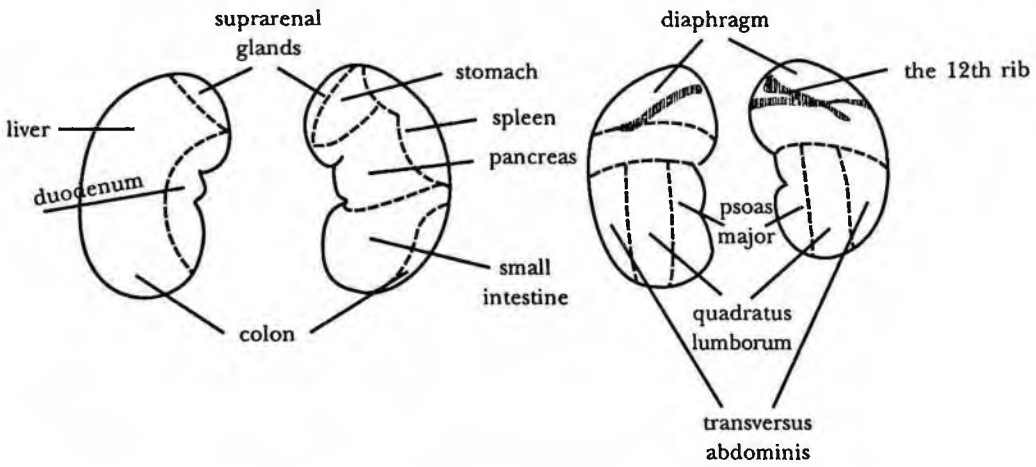

Fig. 9.2 Projection of the anatomy of the kidney.

central indentation of the concave surface is called the hilus of the kidney, where the renal artery, renal vein, lymphatics, and nerves pass in and out of. The pelvis passes out of the kidney from here and the renal vein lies anteriorly. If viewed from the top to bottom, the artery is in the middle, the pelvis is behind, the artery is on top and the vein is below.

The capsule of kidney consists of three layers. From interior to exterior, they are the fibrous capsule, adipose capsule and renal fascia. They serve to support and fix the kidneys. The renal adipose capsule is made up of loose connective tissue, besides encapsulating the kidney, it also encapsules the suprarenal glands. The thickness of adipose capsule varies with the individual; the thickness of adipose capsule of a fat person may be over 2 cm. A perirenal abscess is a pyogenic infection and inflammation of the adipose capsule.

The parenchyma of the kidney may be divided into the superficial cortex layer and medulla deep layer. The thickness of the cortex is about 4–5 mm, about 1/3 of parenchyma is mostly made up of glomeruli and tubules. The renal medulla is composed of 8–18 renal pyramids, about 2/3 of the parenchyma. Their bases are continuous with the cortex, their apices protrude into the renal sinus called the renal papillae. Renal lesser calix are found in the membranous tube, which embraces the renal papilla, to form the greater calices and renal pelvis. If the majority of the pelvis is inside the hilus of the kidney it is called the intrarenal-type pelvis; if the majority is outside the hilus of the kidney, it is called the extrarenal-type pelvis (Fig. 9.3). There are anatomical variations which may be tubular or branched in form. The pelvis becomes narrower at the internal inferior part outside the hilus of kidney to join the upper end of the ureter.

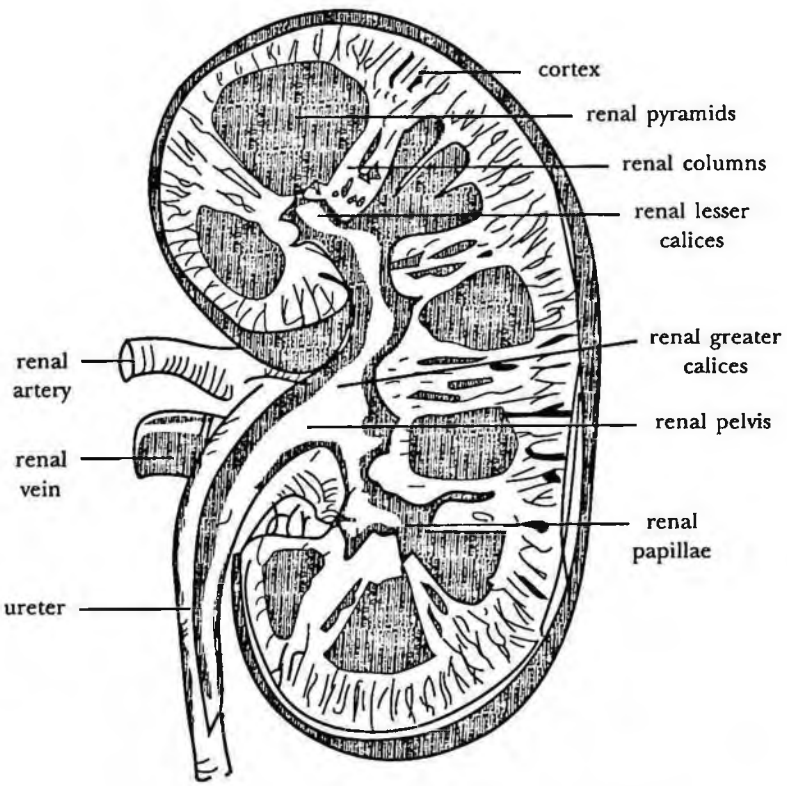

Fig. 9.3 Structure of the anatomy of the kidney.

9.2. METHOD OF ULTRASONIC IMAGING DETECTION

9.2.1. Condition of the Apparatus

Most of the time, linear array ultrasonic imaging apparatus is applied. The frequency used, in general, is 3.5 MHz. Also, a sector or arc-type probe is used. For children, we mostly use the frequency of 5 MHz.

9.2.2. Position of the Patient

9.2.2.1. *Supine Position*

This position is often used. The probe is placed on the right side, through the liver as the echolucent window the right kidney is examined. On the left side, the coronary section is used to examine the left kidney.

9.2.2.2. *Prone Position*

Raise the lumbar region by packing a pillow on the abdomen to facilitate the revealing of the kidney and upper segment of the ureter.

9.2.2.3. *Upright or Sitting Position*

This position is used for the purpose of understanding the motility of the kidney and the localization of the body surface of the kidney.

9.2.2.4. *Decubitus Position*

This position causes the kidney to move to the anterior internal side, so that it is easier to examine below in the costal margin. A pillow may also be used to pack the lumbar region of the patient, so as to widen the space between the costal margin and pelvic cavity, hence making it easier to display the kidney.

9.2.3. Method of Examination

9.2.3.1. *Position of Examination*

(a) Dorsal side examination
For examination, the patient is placed in the prone position, inferior to the costovertebral angle at the back and along the axis of the kidney. Follow the long axis to move the probe right or left laterally to display different sections of the long axis, then do a short-axis-sweep perpendicular to the long axis. Dorsal examination does not interfere with the gas in the gastrointestinal tract, usually it is clearly displayed. But for a fat person and for a person with rather well-developed back muscles, the sound beam is markedly attenuated and the image is not clear. At this point of time another position should be taken for examination.

(b) Ventral examination
The patient lies flat when examining the right kidney. The probe may be perpendicular to the anterior abdominal wall and the liver is taken as the echolucent window. Moving along the right intercostal space or right costal margin, make an oblique or longitudinal section of the kidney, or place the probe horizontally on the lateral wall of the abdomen and take the liver as the echolucent window to examine the right kidney. When examining the left kidney, the spleen cannot serve as the echolucent

window of the left kidney because the normal volume of the spleen is too small. At this point of time, the probe may be placed horizontally on the lateral wall of the abdomen in order to display the left kidney. If the spleen is enlarged, the probe may be placed perpendicularly on the anterior wall of the abdomen, using the enlarged spleen as the echolucent window. If the left kidney is not examined through the lateral wall of the abdomen, the probe should be moved towards the back and inclined a little bit forward to examine the left kidney.

(c) Lumbar region examination
That is the coronary section of the left and right kidney. This position of examination is also one of the positions used to examine the left and right suprarenal glands. It is also good for comparison by X-ray localization.

9.2.3.2. *Method of Examination*

(a) Distention of the abdomen and deep inspiration
These cause the internal organs like the liver, spleen, pancreas and gall bladder, etc., to be displaced inferiorly to the costal margin, which is favorable for the display of the kidney. At the same time, by distention of the abdomen or deep inspiration, the patient's diaphragm will contract causing the viscera to be pushed towards the anterior abdomen. This is also favorable for the display of the kidney.

(b) Method of sector scanning
This method is suitable for the display of the entire kidney. The probe is moved from one side of the kidney, through the central section gradually to another margin of the kidney, making axial movements to scan the whole kidney along its long axis. Otherwise, the probe is moved from one end of the kidney, passing through the entire kidney, to the other end of the kidney so as to make a continuous cross-section scan of the kidney. It is suitable for displaying the small focus in the kidney, collecting system, the para-pyrimidal polycyst, and the difference between the renal pyramids and tumor.

(c) Method of adding pressure on the probe
Add pressure on the skin with the probe to compress the tissues between the kidney and skin. This decreases all kinds of artifacts of the kidney produced by reflection and refraction during the transmission of ultrasound. This makes the sonogram clear, and at the same time it is helpful in differentiating the nature of a tumorous mass such as the echoless and solid tumor. But avoid using too much force when pressure is being applied, as this will cause discomfort to the patient, with other untoward consequences.

(d) Select the most favourable position for examination according to the position of the lesion.
For example, for the upper pole of the kidney, examination is usually done from the back. For the lower pole, it is usually done on the lumbar region. During examination on the horizontal of the hilus of the kidney, one should notice whether there is a tumor or enlargement of lymph nodes in the nearby renal blood vessels and in the hilus of kidney.

9.3. SONOGRAM OF A NORMAL KIDNEY

Sonograms can accurately reflect the anatomy and morphological structure of the longitudinal, transverse and coronary sections of the kidney. The shape and size of the image varies with different sections. The sonogram of a normal kidney is divided into four parts:

(a) Perirenal part
It can usually display the outline of the kidney. Its surface is smooth, the adipose capsule around the kidney mostly presents a low echogenic silent ring. Its thickness varies with the individual, for example, that of a fat person may reach about 2 cm while the thickness in a lean person is very thin, so the outline of the kidney is not clearly displayed.

(b) Renal parenchymal part
The surrounding parts present even low-level echoes at the renal cortex, while the renal pyramid presents round- or triangle-like low-level echoes. The surrounding renal collecting system presents a radiated arrangement. In lean people, teenagers or children it may be clearly displayed, sometimes it may be mistaken for small cysts. In the space between the renal cortex and pyramid, one may sometimes find short, linear or dot-like strong echoes of the blood vessel walls.

(c) Collecting system part
The central part of the kidney is the renal sinus area including the renal collecting system, blood vessel and fat, presenting irregular, strong echogenic dots, coarse, fine or uneven dots. In between, there is a separation of echoless small silent areas by the echoes of urine in the pyramids and renal calices. Overfilling of the urinary bladder will increase the silent band, it is often mistaken for a mild degree of hydronephrosis. A width (of silent area) within 1–1.3 cm is normal. The width of the strong echo area of a normal kidney and the width of the low-level echo area of the parencyma are identical.

(d) Area of the hilus of the kidney
The cross-section at the hilus of the kidney is horseshoe in shape. The outline of the kidney has the appearance of cocavity in this place. When the kidney is lobulated, the sonogram may also reveal a place of cocavity or protrusion. Near the hilus of the kidney, one may find an echoless silent area of a branch of the renal vein. Examination on the abdominal side will display them more easily. The renal vein is bigger than the renal artery. The renal artery has pulsation, in the hilus of the kidney, one may find the echoless silent area of the renal pelvis.

A normal kidney is long-transverse oval in shape, the range of its longitudinal diameter is 10–12 cm, the wide diameter is 5–6 cm, and the thickness is 3–4 cm (Fig. 9.4).

9.4. ANALYSIS OF THE ABNORMAL SONOGRAM OF THE KIDNEY

9.4.1. Enlargement of the Kidney

For unilateral side enlargement, the following conditions should be considered:

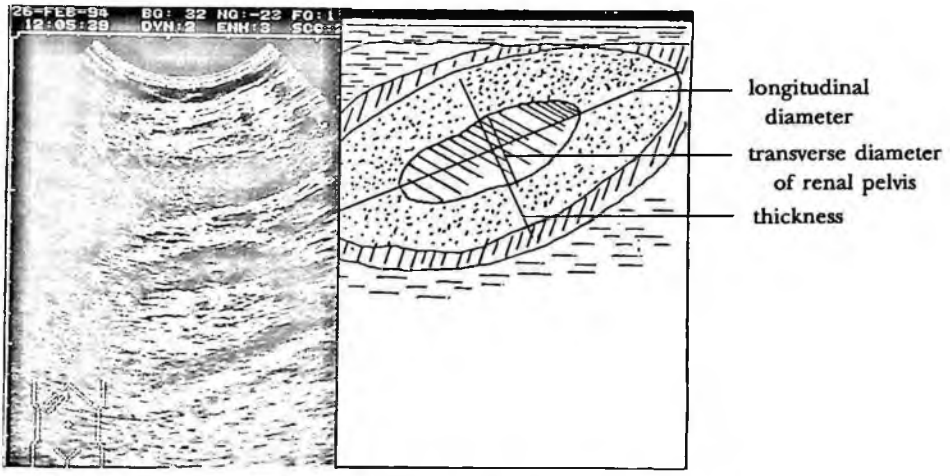

Fig. 9.4 Measurement of the diameters of the kidney.

(a) Normal structure of the kidney
One mostly sees a unilateral compensative enlargement, while other abnormalities are nephrectomy, atrophy due to pathological change, abnormal development, or serious renal function damage like grave hydronephrosis;

(b) Enlargement of the collecting system
The cortex becomes thinner and in the late stage of arteriosclerosis the renal cortex becomes thinner due to fibrosis. Too much fat in the collecting system causes an increase in the width of the strong echo area of the collecting system;

(c) Localized lesion
The kidney cyst, tumor or abscess are examples of such (Fig. 9.5).

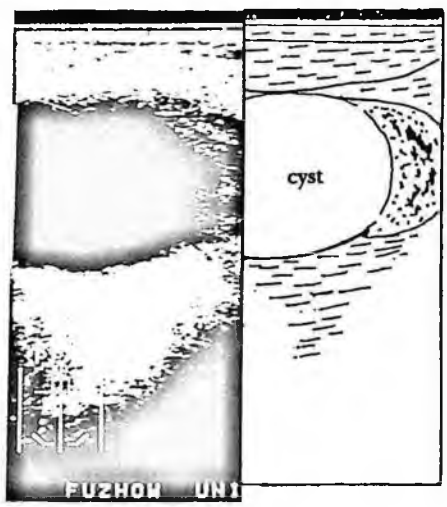

Fig. 9.5 Kidney cyst.

(d) Diffusive lesion
Perinephric effusion, abscess or tumor (Fig. 9.6) hydronephrosis of pyonephrosis (Fig. 9.7).

Fig. 9.6 Diffusive enlargement of the kidney due to a tumor.

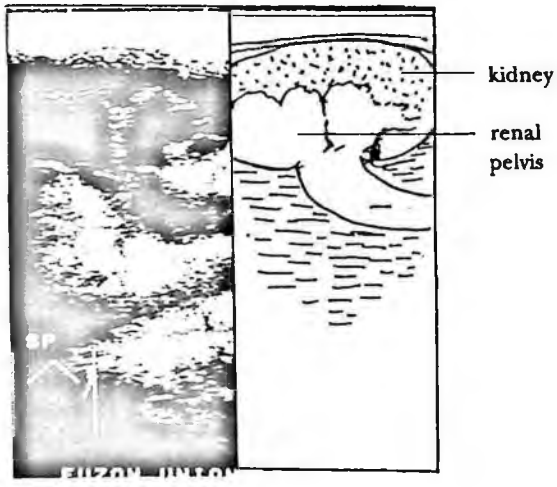

Fig. 9.7 Hydronephrosis.

For a bilateral enlargement of the kidney, the following diseases should be considered:

(a) Normal structure, due to variation among the individuals, of a well-built diabetic patient;
(b) Polycystic kidney or multiple cysts in the kidney;
(c) Hydronephrosis;

(d) Amyloid degeneration of the kidney, showing enhancement of the echoes of the renal cortex;
(e) Acute necrosis of the renal tubules, showing swelling of the kidney. The boundary of the renal pyramid is clear;
(f) Acute renal venous throbosis or obstruction of tumor embolism, enlargement of the kidney with low-level echoes. Thrombosis may be located in the renal vein or inferior vena cava.

9.4.2. Shrinkage of the Kidney

For unilateral shrinkage, the following conditions should be considered:

(a) Incomplete development;
(b) Inflammatory lesion at the late stage of tuberculosis of the kidney;
(c) Old thrombosis of the artery;
(d) Late stage of renal stone.

For bilateral shrinkage one should consider:

(a) Late stage of chronic nephritis;
(b) Bilateral renal arterial stenosis.

9.4.3. Localized Thickening of the Renal Cortex

If the echo of a localized thickness of the cortex is identical to the echo of the nearby renal cortex, one should consider the lobular kidney of the fetus to cause the bulging of the cortex, (its capsule is also lobulated) or localized hyperplasia of the kidney. If the localized cortex becomes thinner by contraction of a scar caused by trauma, another part becomes thicker by compensatory enlargement or equal echo tumor. If the echo of the localized cortex is lower than the echo nearby, it mostly indicates the presence of hematoma, an abscess, or a tumor. If the echo is stronger than nearby, it mostly indicates that tumor and hematoma is often seen.

9.4.4. Diffusive Thinning or Thickening of the Renal Cortex

Diffusive thinning of the renal cortex is mostly seen in the late stages of nephrosis, it is usually accompanied by shrinkage of the kidney and enhancement of the echoes. It is also seen in hyperadiposity, showing an increase in the echo area of the collecting system. Diffusive enchancement of echo and diffusive thickening of the renal cortex are mostly accompanied by the enlargement of the kidney and a decrease in the echoes of the cortex, such as acute interstitial pyelonephritis, or in serious generalized infection. If enlargement of the kidney is accompanied by enhancement of the echoes of the cortex, it most likely indicates amyloid degeneration.

9.4.5. Abnormal Echo of the Pyramids

Enhancement of the echoes of the renal pyramids mostly indicates renal calcification of the medulla. Normal echoes of the pyramids deviated to lower level also appear round-shaped sometimes. This should be differentiated from necrosis of the renal calices, renal papillae, parapelvic cyst, low-level echoes or echoless localized masses such as hamartoma, abscess or tumor.

9.4.6. Abnormal Echo of the Collecting System

9.4.6.1. *Widening of the Echo Area of the Collecting System*

This is mostly due to too much fat surrounding the pelvis. This sonogram shows generalized thinning of the renal cortex, generalized enlargement of the kidney or large amount of stones in the collecting system.

9.4.6.2. *Displacement of the Echo Area of the Collecting System*

Common causes are oppressive displacement of the tumor in the kidney, parapelvic cyst or renal aneurysm. It may also be due to a pseudo tumor in the kidney. The sonogram shows deformed displacement of the strong echo area of the collecting system, or irregular changes.

9.4.7. Separation of Echo of the Collecting System (Expansion)

In the accumulation of fluid in the renal calices and pelvises, one may sometimes find a separation of the strong echogenic dots of the collecting system. The echoless silent area inside is expanded, and may appear as localized or diffusive expansion. The common causes are:

(a) Obstruction of the pelvis
This is mostly due to obstruction by a pelvic tumor, stone or blood clot. The sonogram of the tumor is rather constant, whether regular or irregular in form. The echo of the stone is rather strong and is mostly accompanied by acoustic shadows. A blood clot can often be seen moving or floating when the body position is changed;

(b) Obstruction of the ureter
Common causes are stenosis of the ureter, stone tumors, oppression by enlarged para-abdominal aorta lymph nodes, or oppression by para-abdominal aorta tumor. The sonogram often displays the causes of the obstruction. Lymph nodes present many oval low-level echo masses, most stones have acoustic shadow. A para-abdominal aorta tumor should be differentiated from the contents of the intestinal tract. The former does not change in shape after pressure is exerted by the probe, while the latter will cause shrinkage of the intestinal tract. The tumor changes in shape or disappears (Fig. 9.8);

(c) Obstruction of the lower segment of the ureter
It occurs at the juncture of the ureter and urinary bladder. Examples of obstruction are stone and congenital ureteral cyst;

(d) Vesical lesion
A tumor, stone and hematoma at the vesical trigone may cause the evacuation of the urinary bladder, leading to oppression of the ureter by overfilling the bladder, resulting in hydronephrosis;

(e) Oppression of the ureter by a tumor in the pelvic cavity
Benign and malignant tumors of the uterus and ovaries, absesses of the pelvic cavity and annex or hypertrophy of the prostate may all press on the ureter. Even the uterus of a pregnant woman may be a factor of oppression.

Fig. 9.8 Ureteral stone causes nephrosis.

9.5. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE KIDNEY

9.5.1. Cystic Change of the Kidney

9.5.1.1. *Isolated or Multiple Cysts of the Kidney*

(a) Clinic and pathology
It is mostly confined to one side, but it may occur on both sides. The cystic wall is thin, there is no communication with the renal calices or renal pelvis. Inside the cyst is clear, serous fluid. If accompanied by hemorrhage it will be a bloody fluid, with varying sizes. If there is only one cyst, the kidney is called an isolated cystic kidney. If there are more than one cyst, the kidney is called a multiple-cystic kidney.

(b) Sonographic expression
A typical cyst presents a round echoless silent area. The wall is thin, smooth and there is regular enhancement of the echo as its posterior wall. An enhancement effect at the posterior part of the cyst is not easily discovered due to its small volume. A minority of the cysts are lobulated or polycystic. If the cyst is complicated by the presence of hemorrhage or infection, the sonogram may show fine echogenic dots. Some cysts

located at specialized positions inside the renal sinus area are called pararenal pelvic cysts (Fig. 9.9 and Fig. 9.10).

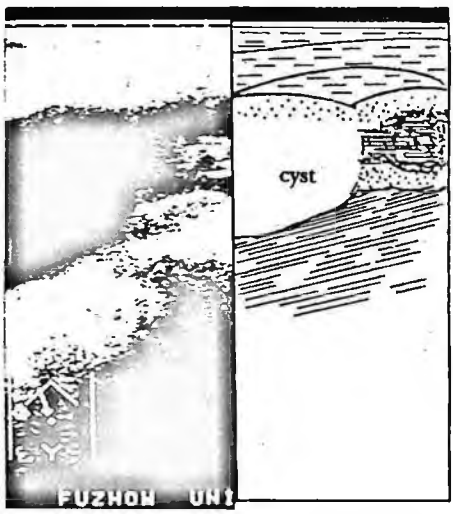

Fig. 9.9 Isolated cyst of the kidney.

Fig. 9.10 Gigantic cyst of the kidney.

9.5.1.2. *Polycystic Kidney*

(a) Clinic and pathology

It is a congenital abnormal development of the kidney. One may find numerous cysts of different sizes inside the kidney. The cysts may occur unilaterally but often they occur bilaterally. They are usually accompanied by a polycystic liver and cysts in other organs.

The adult-type polycystic kidney is commonly seen. The symptoms appear at 40–60 years of age. The main expressions are abdominal mass, lumbar pain, hematuria, hypertension and insufficient renal function. The infantile type is seldom seen but it often appears as insufficient renal function.

(b) Sonographic expression
  (i) Many differently-sized echoless dark areas inside the renal parenchyma;
  (ii) Marked enlargement of the kidney;
  (iii) Partial enhancement of the echo of the renal parenchyma. This is the echo of the cystic wall;
  (iv) Dark areas of the cyst at various sections are round without intercommunication;
  (v) Due to its big volume, the outline of the kidney is unclear;
  (vi) Many cysts with marked disparity of the cysts (Fig. 9.11).

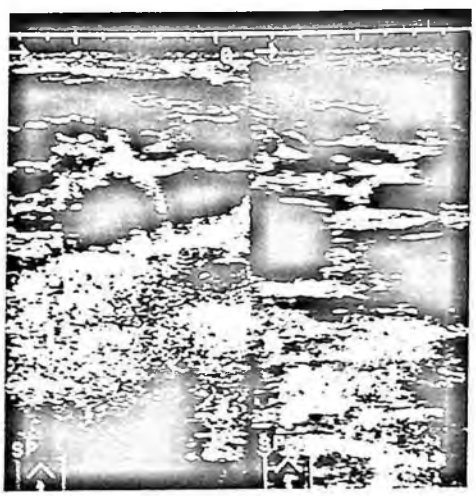

Fig. 9.11 Bilateral polycystic kidney.

9.5.2. Hydronephrosis

(a) Clinic and pathology
It is due to the obstruction of the ureter, urinary bladder or urethra, resulting in retention of urine in the renal calices and renal pelvises. Common causes are congenital stenosis, stone, tumor and hypertrophy of the prostate, and oppression of the pelvic mass. Obstruction at the upper urinary tract often causes unilateral side hydronephrosis; obstruction at the lower urinary tract often causes bilateral hydronephrosis.

(b) Sonographic expression
  (i) Mild hydronephrosis:
  The outline of the kidney is not markedly changed. In the renal sinus area, one may find a narrow band or a flat, dark oval area. Its width is over 1.3–1.5 cm. At this point of time, the comparison of both sides should be noted. If there is mild hydrops on both sides, then overfilling of the urinary bladder or excessive drinking should be concluded. Re-examine after urination. If it is unilateral side, it is mostly due to pathological changes (Fig. 9.12).

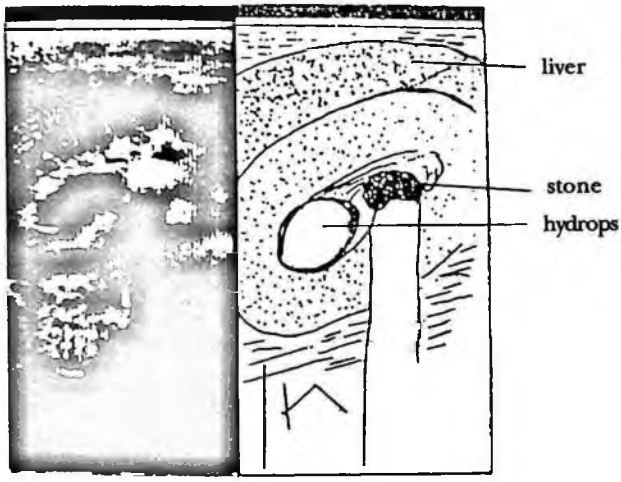

Fig. 9.12 Renal stone causing mild hydronephrosis.

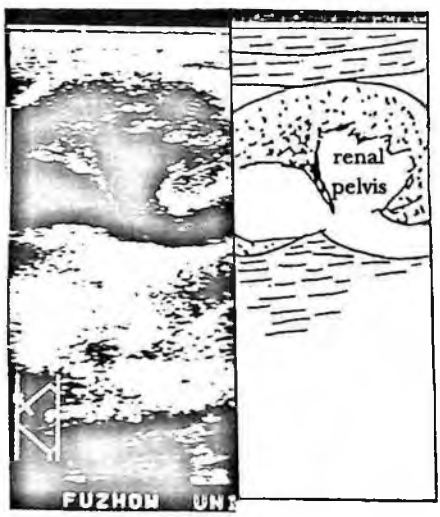

Fig. 9.13 Moderate hydrops in the kidney, presenting pipe-likeness.

(ii) Moderate degree of hydrops of the kidney:
The renal sinus area presents a pipe-like, echoless dark area. Both the renal pelvises and renal calices are markedly enlarged, and the renal volume shows various degrees of enlargement (Fig. 9.13).

(iii) Severe degree of hydrops of the kidney:
The volume of the kidney is enlarged or markedly enlarged. In the renal sinus there is a marked, dilated, cystic echoless area. The parenchyma of the kidney becomes thinner. Sometimes, it cannot be differentiated from a polycystic kidney, but the wall echoes in the cystic dark area of the kidney are spoke-like and there is communication between the dark areas (Fig. 9.14).

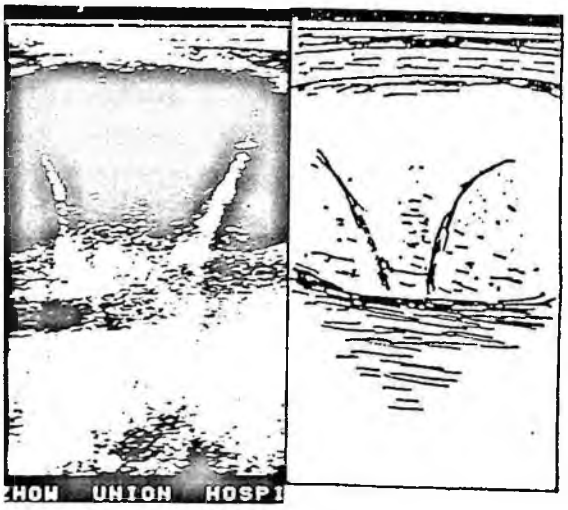

Fig. 9.14 Severe degree of hydrops in the kidney. The renal volume is markedly enlarged and spoke-like echo of wall is found.

9.5.3. Renal Stone

(a) Clinic and pathology

Due to a decrease in urination, dehydration and concentration of urine, there is an increase in the concentration of cystalline material in the urine, leading to disequilibrium between cystals in the urine, such as oxalate, phosphate and urate, with colloids such as mucin. This results in the separating out of the crystalline material in urine to form stones by precipitation, or change in the physiochemical factors in urine, disturbance of metabolism, and inflammation, etc., which will also develop into stones. Clinically, it is often due to hematuria or renal colic that treatment is sought. For example, obstruction of the urinary tract will cause hydronephrosis. Usually, it occurs at the junction of the renal pelvis and the renal calix, or at the renal pelvis and the ureter. The form and size vary, it may be single, in multiples, sand-like, or fill the entire pelvis, forming deerhorn-like stones. About 10% are bilateral, the examination rate of renal stones by ultrasound may reach 85–90%.

(b) Sonographic expression

(i) In the kidney, particularly in the area of the renal sinus, one may find enhancement of the echogenic dots and hyperechogenic masses. At the posterior, these are mainly marked perpendicular acoustic shadows because more than 90% of the renal stones contain calcium (Fig. 9.15).

(ii) The sonographic expression varies with different forms of the stone. The deerhorn-like stone presents irregular branches or several hyper echogenic masses with scattered strong echoes. Muddy sand-like stones may have scattered strong echogenic dots fusing as a mass. Most of its posterior acoustic shadows are rather weak (Fig. 9.16).

(iii) Some sonograms are accompanied by hydronephrosis (Fig. 9.17).

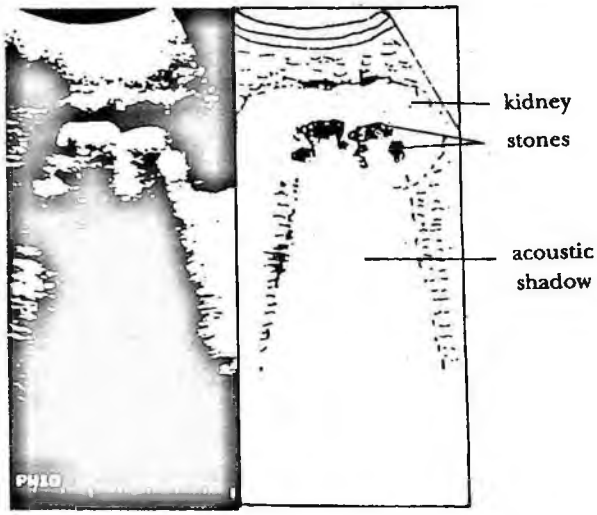

Fig. 9.15 Large amount of stones in the right kidney, appearance of many strong hyperechogenic mass, with marked acoustic shadow at its posterior.

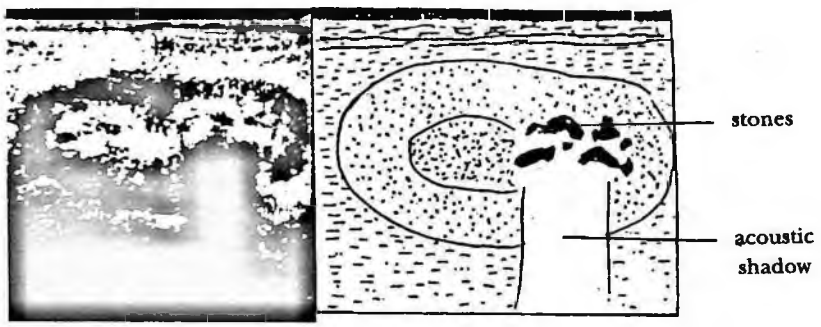

Fig. 9.16 Renal muddy, sand-like stone fusing into a mass.

9.5.4. Renal Tumor

9.5.4.1. *Clinic and pathology*

A majority of renal tumors are malignant. They may be divided into renal parenchymal tumor and renal pelvic tumor. The most common type in the former is the renal cellular carcinoma. In children, the most commonly seen tumor is the Wilms tumor. Benign tumors are seldom seen, but among them, adenoma is the most common. Its volume is small and the diameter is usually about 1 cm. The renal pelvic tumor only constitutes about 15% of all renal tumors. Most of the others are papilloma and transitional epitheliome. The main clinical expression of a renal tumor is painless hematuria. If the volume of the tumor is big, it will cause a pressing pain in the lumbar region. The examination rate of renal tumor by ultrasound is about 85–95%. The smallest diameter examined is 1–1.5 cm.

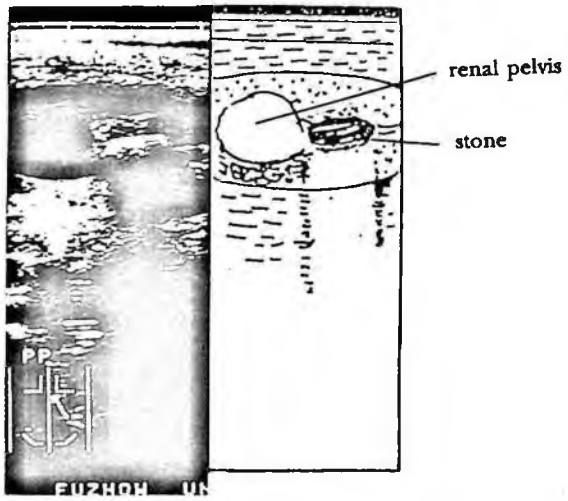

Fig. 9.17 Renal stone accompanied by hydronephrosis.

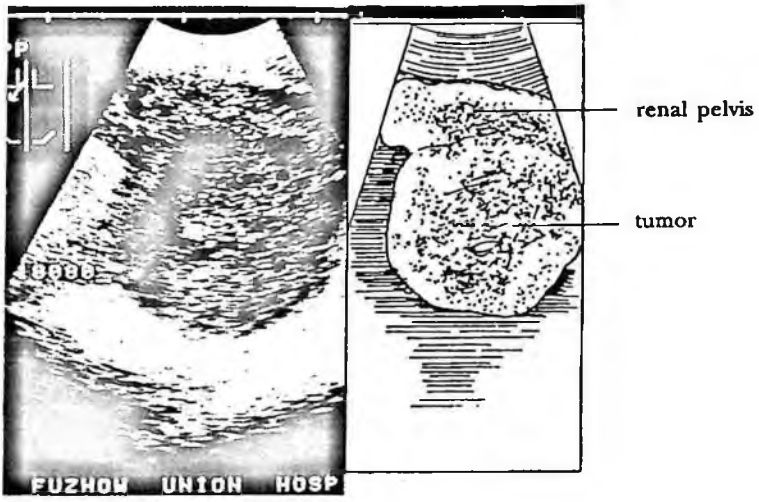

Fig. 9.18 Left renal carcinoma, the tumor protrudes into the abdomen.

9.5.4.2. *Sonographic Expressions*

(a) Enlargement of the kidney may appear to be localized, causing an irregular outline. It may also appear as a diffusive enlargement. If the volume of the tumor is small, the size and outline of the kidney are normal (Fig. 9.18). Sometimes, it may grow outward;

(b) Abnormal echoes of the renal parenchymal are seen. The intensity of the echo varies with the different pathological natures of the tumor. They may be divided into the strong-echo type, low-level echo, equal-echo type and echoless type (cystic-change type). The strong-echo type mostly indicates fibrosis of the presence of calcification tumor;

the echoless type indicates internal hemorrhage, necrosis and liquified changes (Figs. 9.19–9.21).

(c) Echoes at the renal sinus are seen as oppression or invasion of the tumor which will cause displacement of the echoes of a normal renal sinus, deformation, interruption and other changes. But tumors with a small volume or part of the renal parenchymal tumor may also give normal renal sinus echoes. If the separation of the echogenic dots of the collecting system present fork-like tunnelling, and the middle is the parenchymal echo, the tumor should be considered to have already invaded into the renal pelvis.

(d) The margin of the tumor is irregular, the malignant tumor is without capsule, and its posterior may show attenuation.

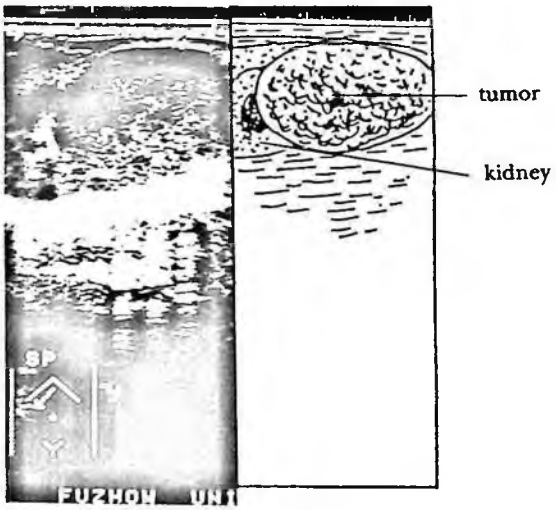

Fig. 9.19 Cellular carcinoma of the upper pole of the right kidney.

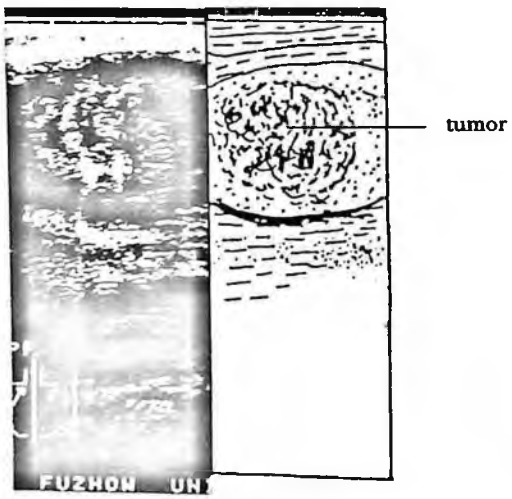

Fig. 9.20 Left renal carcinoma.

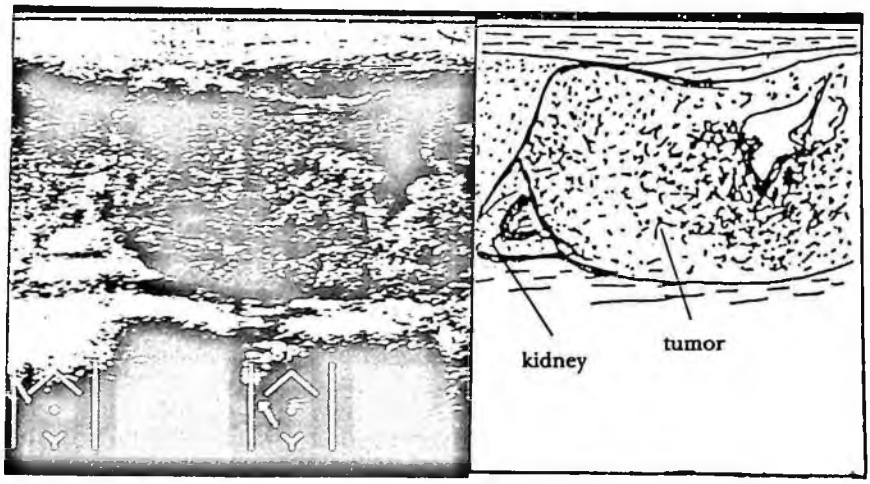

Fig. 9.21 Right giant renal carcinoma (necrotic liquefaction inside).

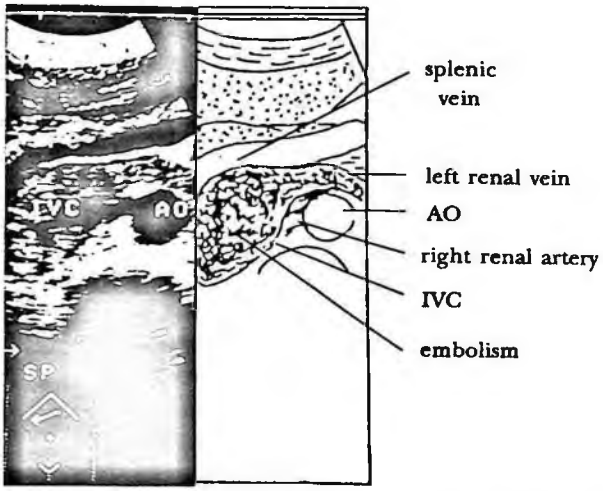

Fig. 9.22 Right renal carcinoma metastasizes into the inferior vena cava.

(e) There are signs of metastasis surrounding the renal tumor. When the tumor is metastasized, one will find swelling of the local lymph nodes and numerous embulism in the renal vein or inferior vena cava (Fig. 9.22). If far-distance metastasis occurs, metastatic focus in the liver and other organs and ascites will appear.

(f) Internal echoes of the renal tumor have connections with the structure and size of tumor cell such as when the nucleus of transparent cell carcinoma is small and the cytoplasm is abundant, the sonogram presents low-level echoes. When the nucleus of the granule cell carcinoma is large and the volume of the cytoplasm is less, it presents a strong echo. Some authors feel that there is great connection between the size of the tumor, for example, small tumors (which mostly present low-level or equal echoes), with gradual increase in volume, the echo will gradually increase too.

(g) If the renal pelvic tumor presents low-level echoes it can be easily diagnosed. If it presents a strong echo, it is not easy to differentiate it from the echogenic dots area of the collecting system. But the pelvic tumor usually causes hydronephrosis, and one may find a substantial body with enhancement of echoes in the liquified dark area (Fig. 9.23).

(h) About 90% of the renal embryonic cell tumors are seen in children under 10 years of age. The sonogram of the tumor varies. Uneven parenchymal tumors may appear as a liquified echoless area, strong echoes and acoustic shadows may also be found due to calcification, so the tumor will be mistaken for multiple renal stones. About 10–15% of the cases occur bilaterally (Fig. 9.24).

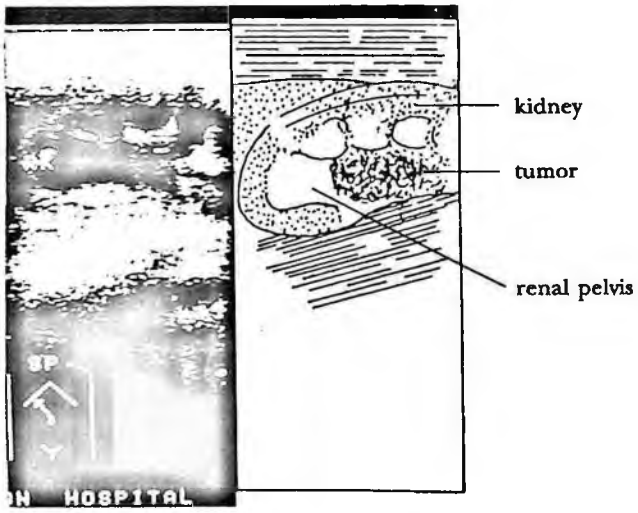

Fig. 9.23 Right renal pelvic tumor.

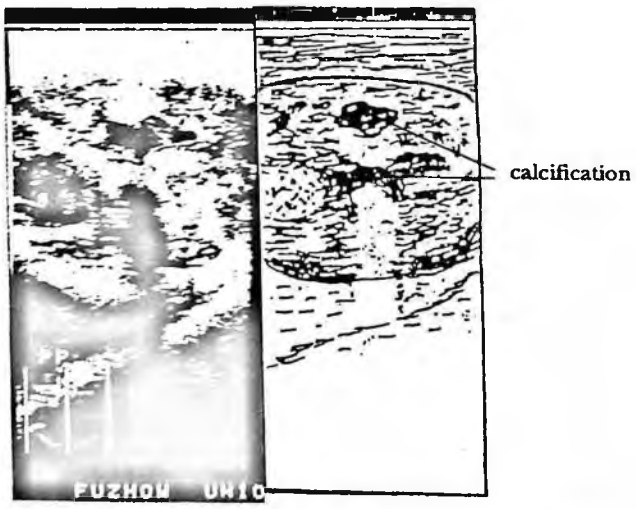

Fig. 9.24 Renal blastoma accompanies calcification.

9.5.4.3. *Ultrasonic Differential Diagnosis of a Renal Tumor*

A sonogram of the renal tumor should be differentiated from that of the intrarenal pseudo tumor and other lesions.

(a) Intrarenal pseudo tumor
It refers to a sonogram coinciding with neoplasm, while the histological expression is the structure of the normal tissue. The commonly seen ones are hypertrophy of the renal column, fetal lobulated kidney and lobulated compensatory hypertrophy. The sonographic feature of the hypertrophy of the renal column is the central extension of the cortex to the medulla. There is indentation around the renal sinus, its echo is continuous with and similar to the cortex, the boundary of the renal sinus is clear and it is mostly located at the upper half of the kidney. One usually sees the symmetrical hypertropy of the renal column. A fetal lobulated kidney is seen in neonates. It usually disappears after 4–5 years of age. If an adult has a permanent fetal kidney, it is due to incomplete fusion of the kidney. The feature of the sonogram is along the inner side of the lateral margin of the kidney, a rather big interlobular groove may be found and, at the surface, one may find lobulated indentation. Due to lobulations, the echo of the tumor nodule can be mistaken to be similar to that of a normal renal parenchyma. Lobulated compensatory hypertrophy occurs in an extensively-scarred kidney. The sonogram may show the outlook of the kidney to be bulb-nodule-like and the intrarenal echoes are often abnormal.

(b) Other diseases
The collecting system will have an echoless area if there is oppression on the artery or vein. It should be carefully diagnosed. The ectopic tail of the pancreas or ectopic spleen may all be mistaken for the left renal tumor, hence one may change the direction of examination for differentiation. In addition, an extrarenal tumor mass, such as the liver, gall bladder, pancreas, spleen and gastrointestinal tumor mass can be mixed up with the renal tumor, particularly the exophytic renal tumor. The anatomical features of each organ and the sonographic features of the renal tumor should be noted for differentiation.

9.5.4.4. *Other Tumors of the Kidney*

Renal lymphoma and lymphosarcoma are all even tissues. The sonograms show mostly low-level echoes of even-textured dark area. Renal hematoma is a type of tumor interlocked by several kinds of tissues, such as unstriated muscles, connective tissues, fat and blood vessels. A commonly seen one is blood vessel leiomyolipoma. The sonogram shows strong echo hyperechogenic mass of reflection of many interfaces. Network echoes may also appear (Fig. 9.25).

9.5.5. Renal Tuberculosis

(a) Clinic and pathology
It is commonly seen in teenagers and is mainly unilateral. The lesion begins from the interface of the cortex and medulla, or inside the papilla, and starts with a local focal

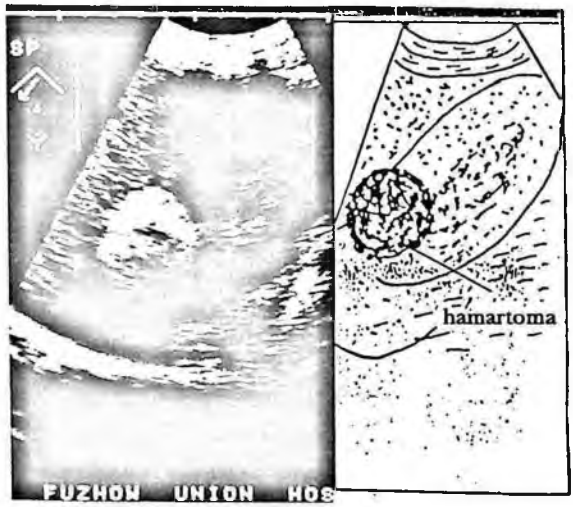

Fig. 9.25 Hamartoma of the lower pole of the right kidney.

lesion. If caseous necrosis occurs, it may destroy the papilla and invade the pelvis, causing caviation, invasion of the ureter and urinary bladder, causing stenosis of the ureter which results in hydronephrosis or pyonephrosis. It may also cause ulceration of the urinary bladder or hyperplasia of the fibrous tissues, leading to opposite ureteral hydronephrosis in the orifice, stenosis and loss of function of the normal sphincter, causing opposite kidney (healthy side).

(b) Sonographic expression

(i) Mild-type renal tuberculosis is without typical expressions, it only shows abnormal echoes of the renal sinus. Sometimes, calcified echogenic dots and light patches may appear.

Fig. 9.26 Hydronephrosis of renal tuberculosis, fibrous change of the renal parenchyma.

(ii) The expressions of severe-type renal tuberculosis are enlargement and irregularity in the outline of the kidney. In the kidney, differently-sized dark areas can be found. If it contains a lot of caseous material, more echogenic dots can be seen in the dark area. If there is calcification of cold abscess, a large number of echogenic dots will be seen. Also, an irregular outline of enhancement of echo will be seen in the boundary, and there may be signs of hydronephrosis. Late-stage atropy of the kidney and calcified putty kidney will be formed (Fig. 9.26 and Fig. 9.27).

9.5.6. Infectious Diseases of the Kidney

(a) Clinic and pathology

The main clinical expressions are irregular fever, inflammation of the urinary system and change in the urinary outline. Main pathological changes are acute pyelenephritis, renal abscess and pyelonephrosis.

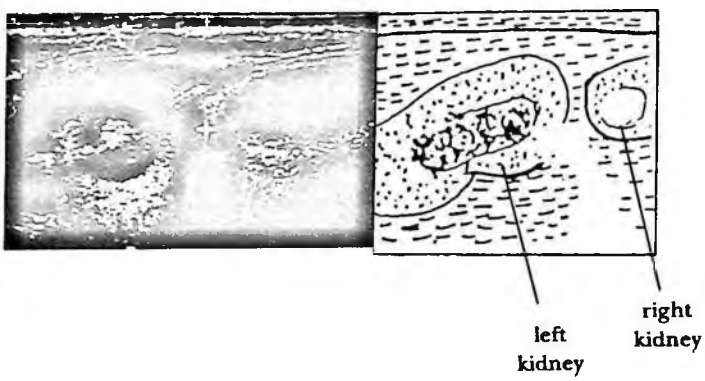

Fig. 9.27 Right renal tuberculosis with atrophy of the kidney. The left kidney undergoes compensatory enlargement.

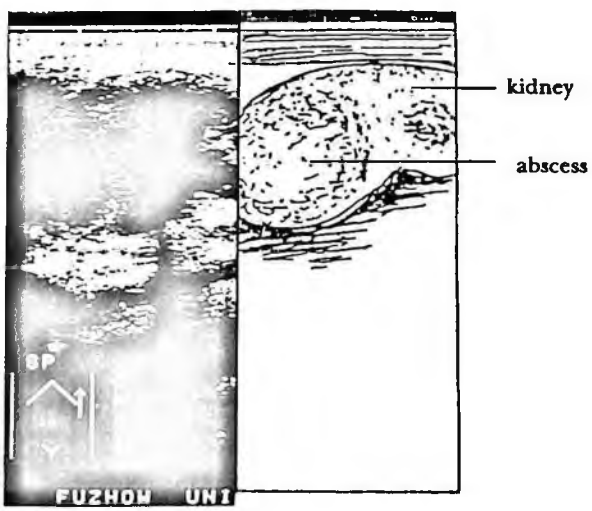

Fig. 9.28 Abscess of the kidney at the upper pole of the left kidney.

(b) Sonographic expression

The sonogram varies with the degree and location of the lesion.

(i) Acute pyelenephrisis: The sonogram is not typical for mild types. For the severe type, one may find unilateral or bilateral enlargement of the kidney. Echoes of the renal parenchyma are low, the sonogram changes greatly in the check-up held not long after the first.

(ii) Renal abscess: The sonogram reveals local enlargement and protrusion of the kidney. The abscess area appears as an echoless dark area or as a honeycomb–like echo area with different intensity. The margin is irregular (Fig. 9.28). If it is a chronic renal abscess, one may find a round echoless dark area with thick walls

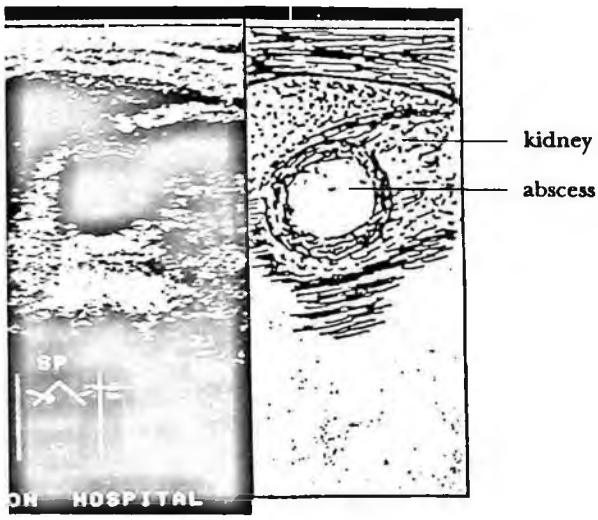

Fig. 9.29 Chronic thickening of the wall of the renal abscess.

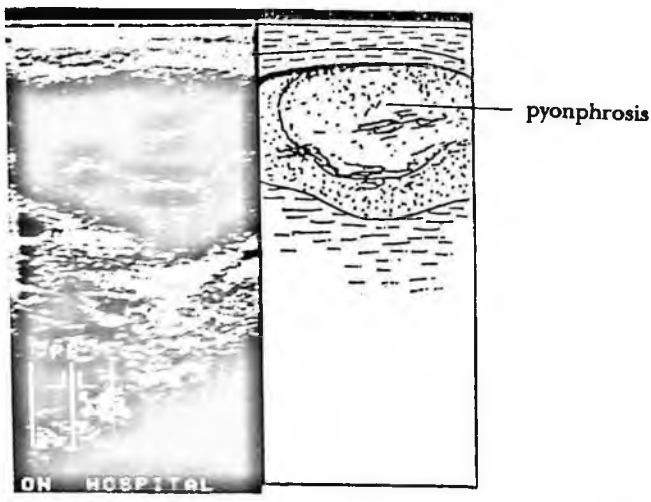

Fig. 9.30 Right side pyonphrosis (accumulation of pus in the pelvis).

and strong echoes. With this, the renal abscess can be differentiated from the cyst of the kidney (Fig. 9.29).

(iii) Pyonephrosis: this disease refers to hydropehrosis complicated with pyogenic infection, resulting in pyonephrosis. The sonographic expression is similar to that of hydronephrosis, but one may find echoes of strong echogenic dots and of tissue fragments in its interior (Fig. 9.30).

9.5.7. Perirenal Abscess

(a) Clinic and pathology

This disease refers to the pyogenic infection of the adipose capsule around the kidney. When an abscess is formed, the adipose capsule of the kidney may be markedly dilated, or it may show localized bulging, mostly secondary to injury or pyogenic infection at the other positions.

(b) Sonographic expression

It reveals a bulging, echoless dark area around the kidney, whose morphology may be round, oval, or band-shaped etc. Sometimes, the giant echoless dark area may protrude to one side. In its interior, one may find minute echogenic dots floating around. The echoes of the renal parenchyma may be normal (Fig. 9.31 and Fig. 9.32).

9.5.8. Nephritis and Incomplete Renal Function

In recent years, many authors feel that the use of ultrasonic images have a definite value in helping to understand the degree of the lesion of nephritis, particularly chronic nephritis. Since essential pathological changes of this disease are seen in the renal cortex, the degree of the lesion of nephritis, as seen by the sonogram, may be divided into three types:

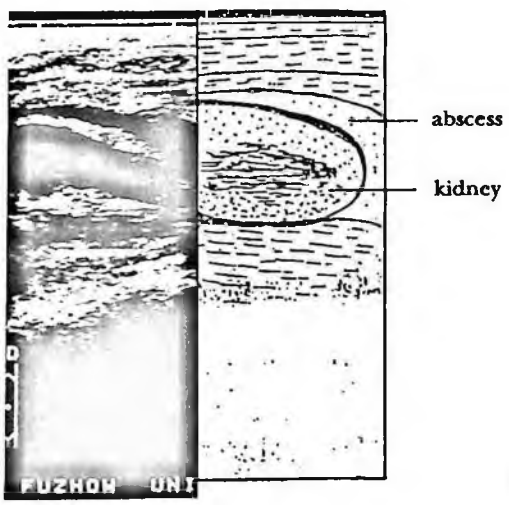

Fig. 9.31 Perirenal abscess.

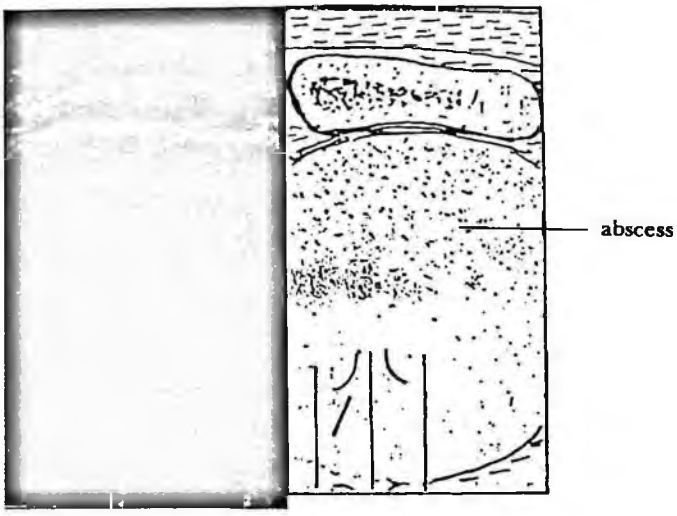

Fig. 9.32 Giant abscess around the left kidney.

Type I — There is no marked abnormality in the outline of the kidney. The margin is regular. The echogenic dots of the renal cortex increase and become coarse, with enhancement of echoes and lack of echoes in the pelvis is normal.

Type II — Echoes of the renal cortex increase unevenly and become coarse. Echo of the renal medulla is not clear, and the demarcation between the renal parenchyma and renal pelvis is also unclear;

Type III — Atrophy of the kidney occurs, its morphology is abnormal, the margin is hazy and unclear. There is marked enhancement in the echo of the renal cortex. Its demarcation with the renal pelvis is unclear, and the echo of the renal collecting system is relatively increased (Fig. 9.33).

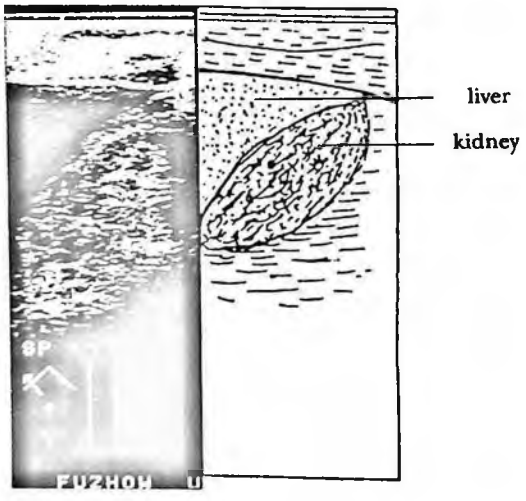

Fig. 9.33 Chronic nephritis atrophy of the kidney.

In acute incomplete renal functioning, an enlargement of the kidney occurs. The echoes of the renal cortex decrease but there is an increase in the width, as a result in the ratio of the echo of the renal cortex to the echo of the collecting system is over 1. The medulla and cortex are hence easily distinguished. In chronic incomplete renal functioning, most cases show atrophy of the kidney and uneven enhancement of the echoes of the renal parenchyma, thus the ratio of the parenchyma to the collecting system is less than 1.

9.5.9. Congenital Abnormal Development of the Kidney

Patients with congenital abnormal development of the kidney are few. They are divided according to pathological changes.

9.5.9.1. *Duplicate Pelvis*

The sonogram shows a normal outlook of the kidney or an elongation of the long axis. Inside the kidney, one may find a double collecting system forming a bridge-like structure, which divides the strong echoes of the collecting system into two segments. Such a structure may be called the "separated sinus sign". It is mostly located between the pelvises (Fig. 9.34). If hydrops occurs in duplicate pelvis, dilatation of the double pelvis will be seen. A duplicate ureter may also be found (Fig. 9.35).

9.5.9.2. *Ectopic Kidney*

The kidney is not examinable from the kidney position, but it can be examined from the abdominal cavity, pelvic cavity or another position. Its morphology is often somewhat smaller, or it appears lobulate, triangular or oval in shape (Fig. 9.36).

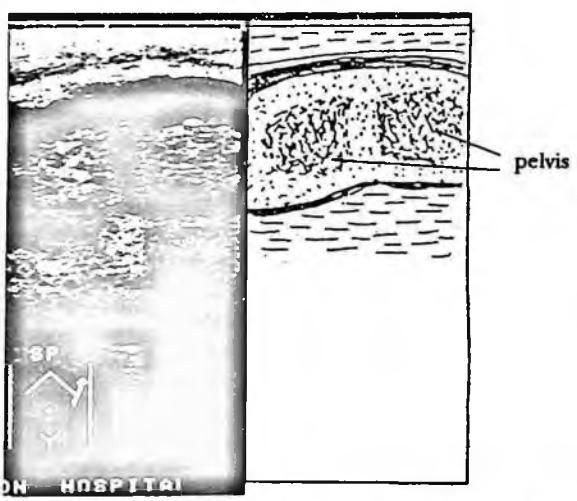

Fig. 9.34 Duplicated pelvis forming a "bridge-like" structure.

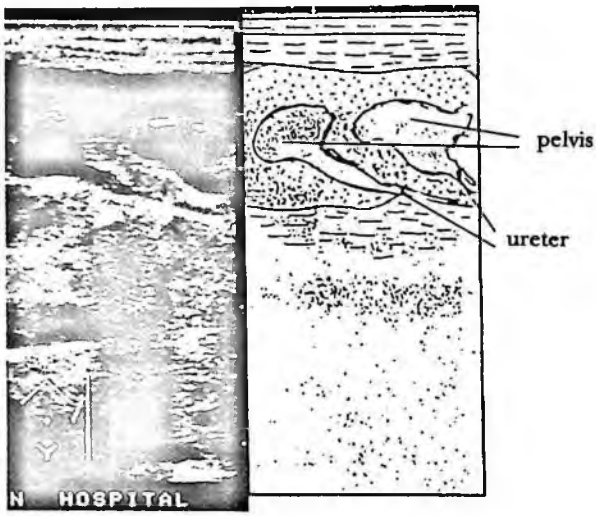

Fig. 9.35 Duplicated pelvis accompanied by hydrops, showing double pelvis and double ureter.

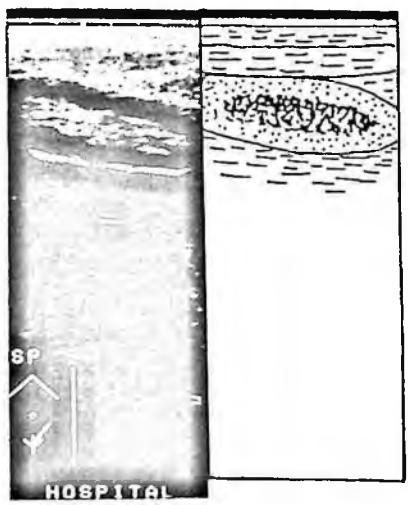

Fig. 9.36 Ectopic kidney in the pelvic cavity.

9.5.9.3. *Absence of the Kidney*

This mostly occurs on one side of the kidney region where no kidney is detected. Ectopic kidney and a bad display of atrophy of the kidney must be excluded. Most of the time, the other side of the kidney has a compensatory enlargement.

9.5.9.4. *Underdevelopment of the Kidney*

The kidney shows up as a small kidney, but the ratio of the echo of the renal parenchyma to the collecting system is normal. By this, it can be differentiated from the atrophy of the kidney.

9.5.9.5. *Congenital Abnormality of the Kidney*

This is expressed as the kidney being shrunken on one side and enlarged on the other (Fig. 9.37).

9.5.9.6. *Polycystic Kidney*

This mostly occurs bilaterally and is often accompanied by a polycystic liver.

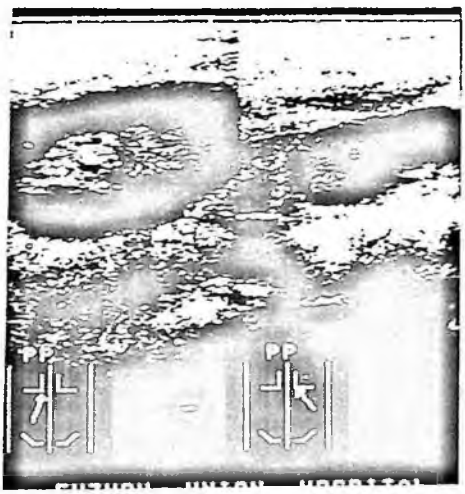

Fig. 9.37 Congenital abnormality of the kidney, right side atropy of the kidney, and enlargement of the left kidney.

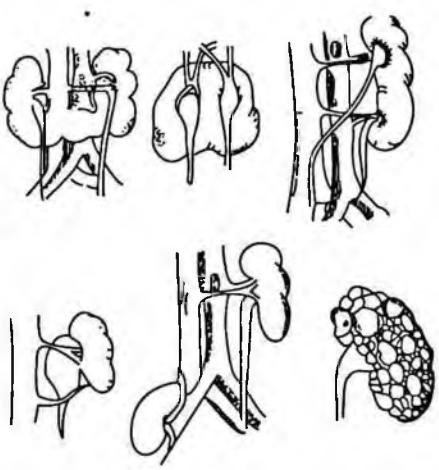

Fig. 9.38 Congenital abnormal development of the kidney. Top row: left — horseshoe kidney; middle — "cake" kidney; right — duplicate kidney. Bottom row: left — hydronephrosis; middle — ectopic kidney; right — polycystic kidney.

9.5.9.7. *Fusion of the Kidney*

This may appear as a mass-like S-type or horseshoe-type kidney (Fig. 9.38).

9.5.10. Nephroptosis

Nephroptosis is often seen in lean and tall people with relaxed abdominal muscles and poor nutrition. The standard diagnosis of the sonogram is that the degree of motility of the kidney is over 3 cm, and the lower pole of the kidney is below the line joining the two ileiocrest. Care should be taken to exclude the tumor of the upper pole of the kidney and displacement of kidney due to a suprarenal tumor.

9.5.11. Transplantation of the Kidney

Along with extensive application of the transplantation kidneys in clinics, contemporary ultrasonic imaging has been an important imaging diagnositic procedure for routine examinations of transplantations of the kidney.

Often the phenomenon of rejection occurs particularly after the transplantation of a kidney. It may cause obstruction of the ureter, accumulation of fluid around the kidney, urinary fistula, perirenal lymphatic cyst, hematoma, abscess, stenosis of anastomosis of the renal blood vessel, and other complications. Ultrasonic imaging plays an important role in diagnosis and differential diagnosis of rejection.

9.5.11.1. *Method of Ultrasonic Examination of Kidney Transplantation*

In general, this method of examination is identical to the method of examination for one's own kidney. Since all transplanations of the kidneys are usually done to one side of the lower abdomen of the patient, approximately at the iliac fossa, the position is shallow and is directly adherent to the skin of the abdominal wall without interference from the gas of the gastrointestinal tract and rib. It is more favourable to use ultrasonic imaging, and one may use a high-frequency probe, such as a probe of 5 MHz, to get a clearer image. One may also apply force suitabily on the probe, and use the long axis and short axis section to scan the whole kidney and its surroundings. Usually, the examination is done after proper filling of the urinary bladder. The time for the first ultrasonic examination depends on different cases. Some people advocate the carrying out of the examination immediately after surgery or within 24 hours, some after 4–7 days. The author suggests that, unless in an emergency, an examination should only be done several days after the surgery, in order to avoid wound infection.

9.5.11.2. *Sonogram of a Transplated Kidney*

The sonogram of a normally transplated kidney is similar to that of one's own kidney. The renal pyramid of the former is often much clearer than that of the latter. Transplanted

kidneys often increase a little in volume, but the maximum limit of enlargement should not be over 25% at the end of 2 weeks, and not over 32% at the end of 3 weeks.

9.5.11.3. *Sonogram of Complications in the Transplanted Kidney*

(a) Sonogram of kidney rejection

Within a short period of time, the volume is markedly increased. By the end of 2 weeks the increase is over 25%, and at the end of 3 weeks it is over 32%. Marked enlargement of the pyramid is accompanied by weakening of the echo, which may be diffusive or localized in 1–2 pyramids. An enlarged pyramid will oppress the renal sinus. The echo of the renal cortex is enhanced and its thickness is increased. If it is accompanied by hemorrhagic necrosis, one may find low-level echoes or an echoless area inside the renal sinus. If it is chronic rejection of the kidney, non-compensatory enlargement or shrinkage in the volume of the kidney will occur. Enhancement of the echoes of the renal parenchyma results in the unclear demarcation of the echo between the cortex, medulla and renal sinus (Fig. 9.39).

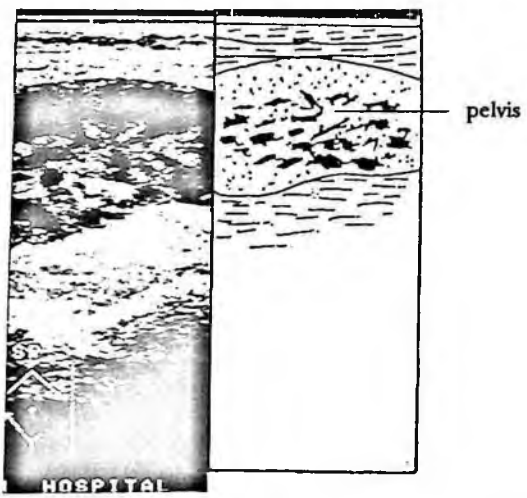

Fig. 9.39 Sonogram of rejection of a transplanted kidney.

(b) Hydronephrosis

Rejection induces hydronephrosis. The sonogram shows marked enlargement of the kidney volume. The echolucence is fairly good, indicating inflammatory stenosis of the ureter, necrosis or hematoma oppression, and other complications.

(c) Accumulation of fluid around the kidney

Accumulation of fluid around the kidney include the lymphatic cyst around the kidney, hematoma, abscess and other echoless dark areas. The lymphatic cyst is usually an echoless dark area. In hematoma and abscesses, minute echogenic dots are often found inside the dark area.

9.5.12. Other Diseases of the Kidney

9.5.12.1. *Injury of the Kidney*

This is divided into contusion of the kidney, partial laceration of the kidney, laceration of the toal layer of the kidney and laceration of the pedicle of the kidney. Sonogram: Echogenic dots of the collecting system at the place of irregular laceration is scattered and disorderly. The pelvis often displays an echoless dark area due to the accumulation of blood. Careful examination may show that the outline of kidney is interrupted, indicating the place of laceration. When massive hemorrhage due to laceration of the kidney occurs, an echoless dark area may be found around the kidney due to hematoma, and the amount of bleeding may be judged by the size of the dark area (Fig. 9.40).

Retroperitoneal hematoma due to laceration of the kideny will not move with changes in the body positions. That means the dark area is rather constant. But if it is intra-abdominal hemorrhage due to rupture of the intra-abdominal organs such as the liver or spleen, the position will move with changes in the body positions.

9.5.12.2. *Functionless Kidney*

A functionless kidney may be caused by hydronephrosis, renal tuberculosis, renal stone, chronic nephritis, atrophy of the kidney, congenital maldevelopment of the kidney, and tumors. The clinical diagnosis is difficult, intravenous pyelography, isatops renogram and other examinations can only indicate that the kidney is functionless, but they cannot diagnose the causes. Ultrasonic imaging can be used to make rather accurate diagnosis of the above-mentioned diseases.

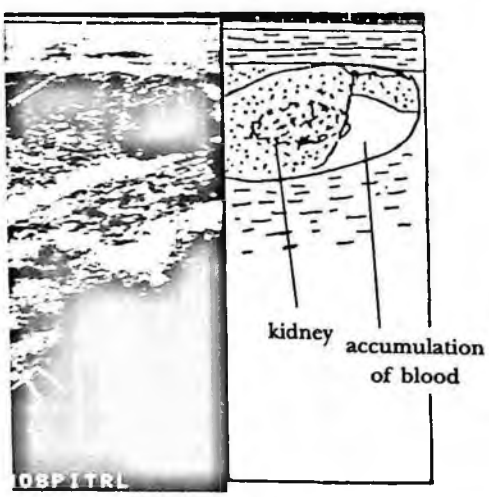

Fig. 9.40 Partial laceration of the kidney with accumulation of blood in the kidney.

9.5.12.3. *Accumulation of the Fluid of the Renal Adipose Capsule*

This is very seldom seen. From Figs. 9.41 and 9.42, one can see that the renal parenchyma loses its normal morphology due to oppression, and a large amount of fluid is accumulated in the adipose capsule around the kidney.

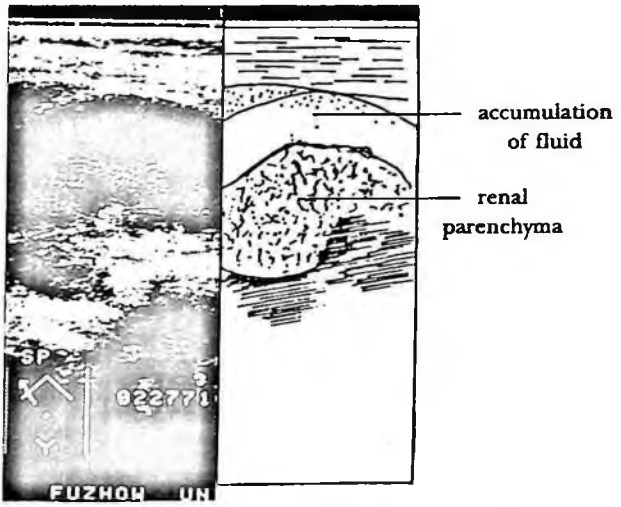

Fig. 9.41 Hydrops of the adipose capsule of the kidney, with oppression of the parenchyma of the kidney.

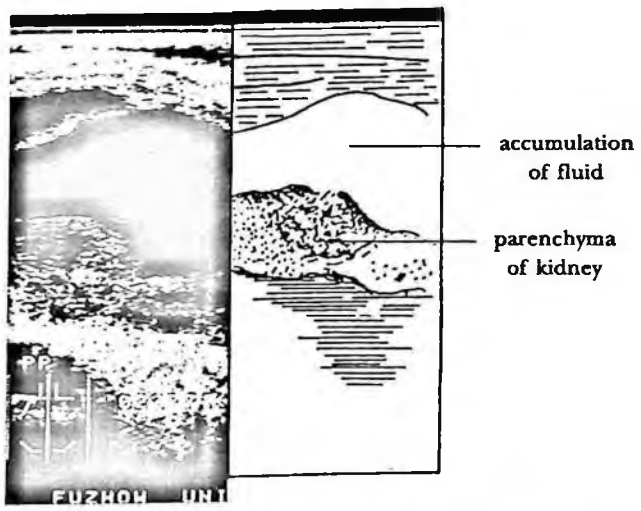

Fig. 9.42 Hydrops of the adipose capsule of the kidney.

Chapter 10

Ultrasonic Imaging Diagnosis of Diseases of the Suprarenal Gland

Lin Liwu

Since the volume of the suprarenal gland is rather small and it is at a special position, the diagnosis of many diseases in the past could only depend on clinical and biochemical examinations. Although CT examinations may greatly increase the rate of diagnosis of the suprarenal gland tumor, it is because of the high expense of the equipment that it is not yet made popular. Currently, ultrasonic imaging apparatus with high resolution can examine tumors of about 1 cm and detect extra-suprarenal gland tumors like pheochromocytoma. Therefore, ultrasound is the first choice for the diagnosis of diseases of the suprarenal gland.

10.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE SUPRARENAL GLAND

The suprarenal gland is located at the upper pole of the kidney, inside the renal fascia. There is fat surrounding it and it is separated from the kidney by loose fibrous tissues. The right suprarenal gland is triangular in shape while the left suprarenal gland is often crescent-shaped. A normal suprarenal gland is, on the average, 4–6 cm in length, 3 cm in width and only 0.2–0.8 cm in thickness. The right suprarenal gland is located at the internal side of the upper extreme part of the right kidney, it is deviated anteriorly. The left suprarenal gland is located at the inner side of the upper part of the left kidney, anterior to the right suprarenal gland. Its inner side is the inferior vena cava, the exterior side is the bare area of the liver and the diaphragm lies to its posterior. The inner side of the left suprarenal gland is the abdominal aorta, its exterior side is the left kidney, to its posterior is the diaphragm, and to its anterior is the pancreas. The splenic artery is at its upper margin while the splenic vein is at its posterior.

The projection of the physical surface: on the section at the first lumbar vertabra, one may clearly find the diaphragm crux on both sides of the abdominal aorta. It may serve as the

indicator for the suprarenal gland level. In addition, the body of the pancreas may serve as the other indicator (Fig. 10.1).

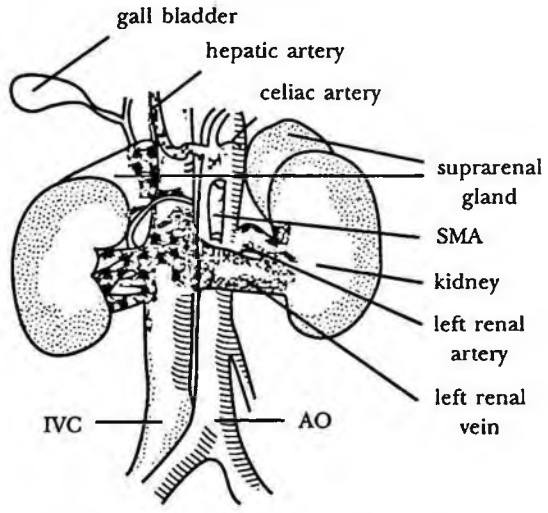

Fig. 10.1 Sketch map of the anatomical position of the suprarenal gland.

10.2. EXAMINATION OF THE SUPRARENAL GLAND BY ULTRASONOGRAPHIC DIAGNOSIS

10.2.1. Apparatus and Preparation by Patient

(a) The sector-type and arc-type ultrasonic imaging apparatus are often applied, the frequency of the probe is 3.0–3.5 MHz; for children, a probe with a frequency of 5 MHz may be used.

(b) The preparations to be done by the patient is similar to that for the examination of the kidney. To decrease the interference from the abdominal gas, it is better to conduct the examination on an empty stomach.

10.2.2. Method of Examination

For the examination of the suprarenal gland, one may assume the supine, decubitus, prone, sitting, and many other body positions to undergo examination longitudinally, transversely and obliquely on the anterior abdominal wall, the waist and the back.

10.2.2.1. *Examination from the Back*

Firstly, examine the long axial surface of the kidney from the back, then move along the long axis of the kidney to the upper pole of the kidney and the suprarenal gland will be displayed. After displaying the adipose capsule around the kidney, one may also search for the upper

pole. Sometimes, the patient may be asked to inhale deeply to let the kidney move down, or he may take the sitting position or upright position for examination.

10.2.2.2. *Examining from the Waist*

When taking a coronary section to examine the suprarenal gland from the waist, the kidney will be displayed first. The sound beam is then gradually moved from the posterior to anterior to take a continuous section for observation. After the disappearance of the echogenic dots in the renal colleting system, the suprarenal gland at the internal side of the upper pole of the kidney may be displayed.

10.2.2.3. *Examination of the Right Suprarenal Gland*

Take the oblique section from the right 9th–10th intercostal space at the mid axillary line. Scanning is conducted from the right suprarenal gland trigone between the right liver, the right kidney and the inferior vena cava. The resolving rate may reach around 80%.

10.2.2.4. *Examination of the Left Suprarenal Gland*

One may also take the oblique section from the left 9th–10th intercostal space at the posterior axillary line, at the left suprarenal gland trigone, namely between the space of the spleen, the left kidney and the abdominal aorta for scanning. But the resolving rate at only about 40%, in general, is poorer than that of the right side. Some authors suggest the use of the celiac vein–suprarenal gland to examine the left suprarenal gland. In this method, the patient assumes a 45° left posterior oblique position, then the sound beam passes through the right liver, inferior vena cava, diaphragm, and abdominal aorta to display the suprarenal gland. By this method, the display of the left suprarenal gland may reach 90%.

10.2.2.5. *Examining from Other Positions*

Some suprarenal gland tumors such as pheochromocytoma have about 10% chance of developing outside the suprarenal gland. Therefore, during the examination, besides careful examination of the suprarenal gland, other positions, such as the paraabdominal aorta, hilus of the liver, hilus of the kidney and the urinary bladder, should also be examined.

10.3. SONOGRAM OF A NORMAL SUPRARENAL GLAND

The sound image of a normal suprarenal gland is rather difficult to display. Its echo is deviated to the low level, its sectional morphology mostly presents a triangular, crescent or V shape.

The long diameter varies greatly but usually not over 3 cm. Surrounding the suprarenal gland is a strong echo light band.

10.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE SUPRARENAL GLAND

10.4.1. Diseases of the Suprarenal Cortex

10.4.1.1. *Hypercortisolism*

In the clinic, it is also called the "Crushing Syndrome". It is developed from hyperplasia of the suprarenal cortex or "cortical tumor". Adenoma is the most commonly seen cortical tumor. Its diameter may reach 3–4 cm, with complete capsules. If it is adenocarcinoma, the volume will rapidly increase within a short period of time. The increase in volume due to hyperplasia of the suprarenal cortex is not identical. It mostly occurs bilaterally, and the clincial expressions are centripetal obesity, purpura, hairiness, and fatigue.

Sonographic expressions: If it is suprarenal adenoma, round tumors of different sizes may be found in the suprarenal gland, the capsule is smooth and regular, and an even low-level echo is found internally. If it is carcinoma, the margin is mostly irregular. If it is hyperplasia of the cortex, an increase in volume will be found in both of the suprarenal glands, showing changes in the light strip or light band echo. Usually, if the suprarenal gland is round in shape with a diameter line of over 3 cm, the suprarenal gland tumor or hyperplasia should be considered. But the suprarenal cortical adenoma is often around 1–2 cm with a smooth boundary and low-level echo. Therefore, the examination must be done very carefully (Fig. 10.2).

10.4.1.2. *Hyperaldosteronism*

The clinical expressions are hypertension, hypokalemia and polyuria. 80% of primary hyperaldosteronism is derived from the superarenal cortical tumor, but for adenocarcinoma it is only about 2%. About 90% of the suprarenal adenoma are single, 10% are bilateral.

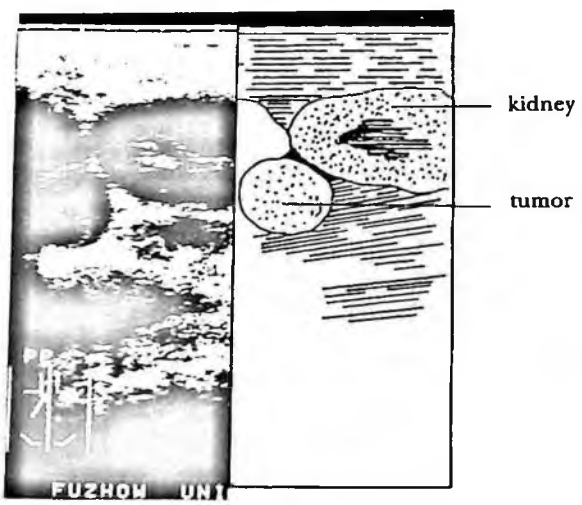

Fig. 10.2 Left suprarenal cortical adenoma.

Secondary hyperaldosteronism is mostly caused by extrarenal diseases such as cirrhosis of the liver. The sonographic expression is similar to that of hypercortisolism (Fig. 10.3).

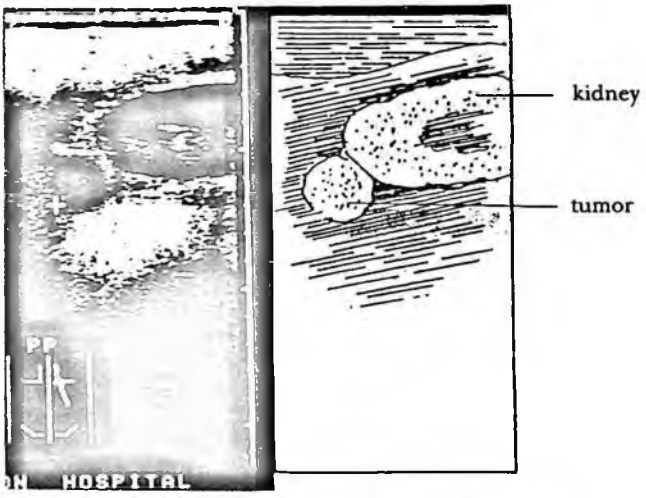

Fig. 10.3 Right suprarenal cortical adenoma.

10.4.2. Diseases of the Suprarenal Medulla

10.4.2.1. *Pheochromocytoma*

They are mostly benign tumors of the suprarenal gland of which about 10% are malignant. About 90% of them grow in the medulla of the suprarenal gland and about 10% grow out of the suprarenal gland, such as in the paraabdominal aorta, abdominal cavity or within the urinary bladder. About 10% of them are bilateral. In addition, about 5% of the cases are complicated by multiple subcutaneous neurofibroma. Clinical complications present various symptoms such as paroxysmal or continued hypertension, sweating, headache, "flushed face" and even hearing failure. The size of the tumor is not proportional to the clinical expression.

Sonographic expression: Due to a great variation in size, the sonographic expresson is also not identical. A patient with a tumor of a fairly large volume will have flatly-rounded or round tumors with different diameters in the inner side of the upper pole of the kidney. Internal echoes are often low-level echoes, with smooth margin. With malignant changes, it may be lobulated or irregular in shape. With fairly big volume, the internal echo may be uneven and the tumor may be found to move up and down with respiration (Figs. 10.4–10.6).

The extra-suprarenal pheochromocytoma often grows near the hilus of the kidney, para to the abdominal aorta (Figs. 10.7 and 10.8), and even in the urinary bladder, abdominal cavity, and thoracic cavity. The left suprarenal pheochromocytoma should be differentiated from the tumor at the upper pole of the left kidney, the enlargement of the lymph node at the hilus of the spleen, and also the tumor of the tail of the pancreas. The author once mistook a case of left suprarenal pheochromocytoma for the tumor of the tail of the pancreas. Hence, this is worth some attention.

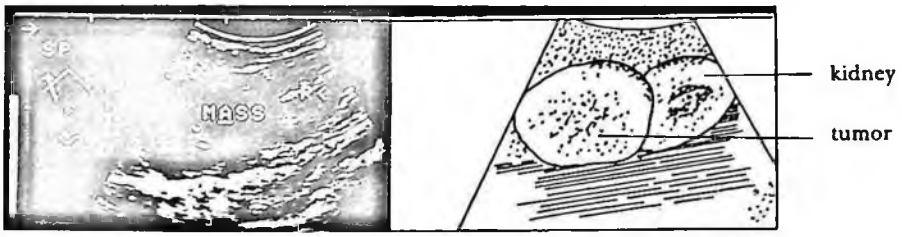

Fig. 10.4 Right suprarenal pheochromocytoma.

Fig. 10.5 Left giantic suprarenal pheochromocytoma.

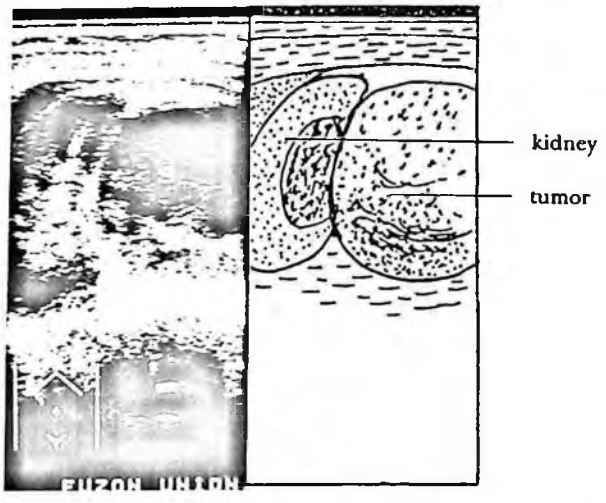

Fig. 10.6 Pheochromocytoma at the right hilus of the kidney (benign).

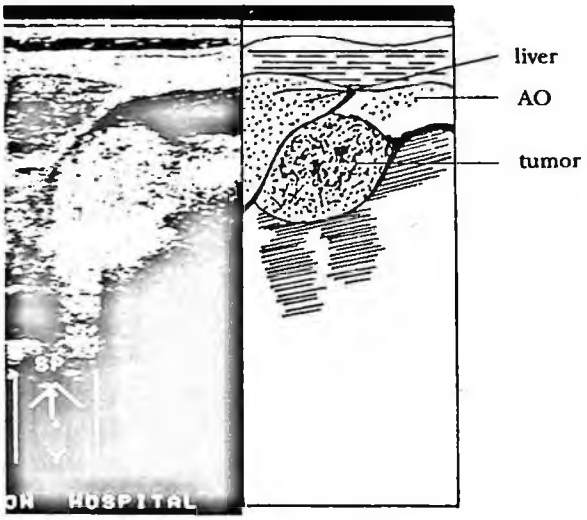

Fig. 10.7 Phenchromocytoma para to the abdominal aorta (longitudinal section).

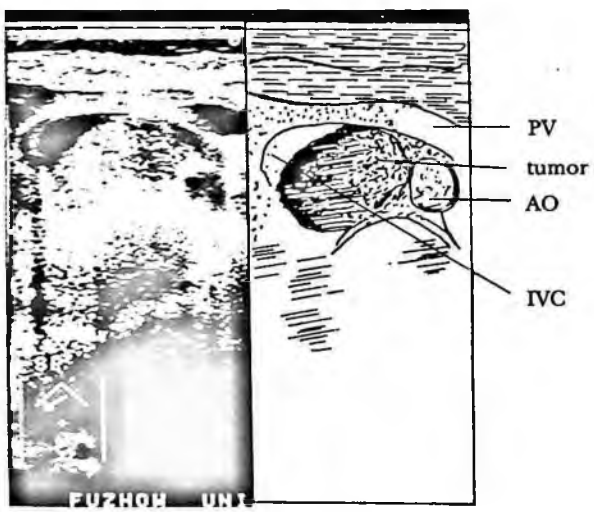

Fig. 10.8 Phenchromocytoma para to the abdominal aorta (transverse section).

10.4.2.2. *Neuroblastoma*

About 50% of it grows in the medulla of the suprarenal gland, and the rest grow outside the medulla of the suprarenal gland such as in the posterior peritoneum, mediastinum and cervical sympathetic ganglion. Neuroblastoma is one of the main causes of abdominal tumor among infants and children, with about 30% in children within one year of age and 80% in children within five years of age. The clinical expression is a rapid enlargement of the abdominal tumor. The tumor often metastasizes to the eye socket. In general, the sonographic expression shows the presence of the nodular echo or strong echo. Once the tumor undergoes hemorrhage or necrosis, an echoless dark area may be found inside the tumor.

Important diagnostic values of ultrasonic imaging on suprarenal gland diseases are:

(a) Diagnosis and localization of the suprarenal gland tumor. According to reports, the sensitivity rate can reach 90%, with about 90% idioathic. With the help of clinical expressions and biochemical examinations, the suprarenal cortical tumor can be differentiated from the medullar tumor. The former is often seen as the Crushing Syndrome and the latter is often seen as pheochromocytoma;
(b) Examining and localizing the extra-suprarenal gland, pheochromocytoma or other tumors in the medulla.

In general, the suprarenal gland tumor has an obvious outline, but the left suprarenal gland tumor should sometimes be differentiated from the spleen. At this point of time, a multi-sectional examination must be done to observe its continuity with the spleen. Tumors of the suprarenal gland which are less than 1 cm cannot be easily displayed by the ultrasonic imaging. Hence, it should be combined with the CT examination for a more accurate diagnosis.

Chapter 11

Ultrasonic Imaging Diagnosis of the Diseases of the Ureter

Lin Liwu, Zhong Xinhua

One of the common causes of renal colic and hematuria is ureteral stone. In the past, medical examiners depended on X-ray for accurate diagnoses (clinically). Now, ultrasonic imaging is used for such examinations. Along with the continued improvements in the nature of the apparatus and the examination techniques, ultrasonic imaging has become an essential diagnostic method for the detection of ureteral stone and other diseases.

11.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE URETER

The ureter is a paired muscular channel, in between the pelvis and urinary bladder. It has a total length of 25–30 cm, and the position of left side is a bit higher. The thickness of the caliber of the ureter is uneven, with an average between 0.5–1.0 cm. Its upper, middle and lower portion, each has a narrow part. The internal diameter of the upper orifice (where it connects with the funnel of the pelvis) is about 0.2 cm, the lower orifice (the part passing through the urinary bladder wall) is the narrowest with an internal calibre of only 0.1–0.2 cm. The internal caliber of the middle portion, where it crosses over the iliac artery, is about 0.3 cm. This is also a predilective place for stones. The ureter has three curvatures, therefore it is divided into three segments: the abdominal segment, which is from the pelvis to where it crosses over the iliac artery; the pelvic segment, which is after entering the pelvis to the place before entry into the urinary bladder wall; and the wall segment, which is in the wall of the urinary bladder and is about 1.5–2.0 cm in length (Fig. 11.1).

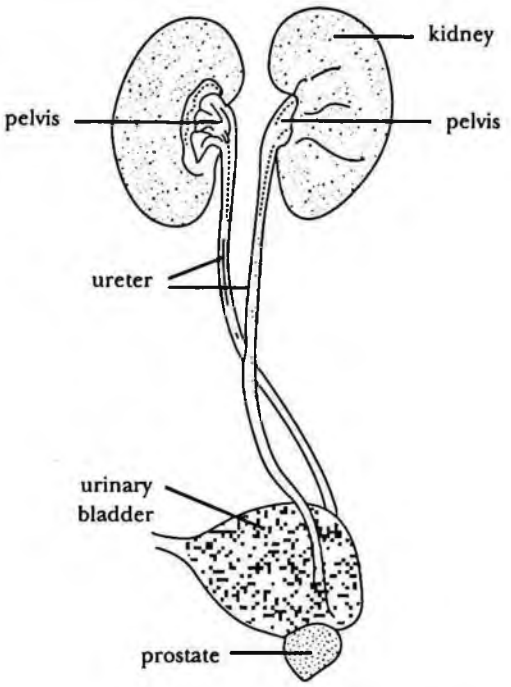

Fig. 11.1 Sketch map of the anatomy of the ureter.

11.2. EXAMINATION BY ULTRASONIC IMAGING

11.2.1. Condition of the Apparatus

In general, the real-time linear array or sector probe is used. A suitable frequency of 3.5 MHz is used, but for children and lean people, a 5 MHz-probe is used.

11.2.2. Preparation to be Done by the Patient

In general, the examination of the ureter should be done during fasting, and the urinary bladder should be filled. Sometimes, a diuretic is given to make every segment of the ureter to enhance the ease of displaying the ureter.

11.2.3. Method of Examination

Multiple body positions and directions can be used for the examination of the ureter. The supine, decubitus and prone positions are commonly used, with different position being determined by different parts. For the upper segment of the ureter, the patient is usually asked to assume the prone position. The examination is done along the psoas major from the back. For the middle and lower segments, owing to influence from the iliac crest bone, the examination is mostly done from the waist or abdominal wall. But gas in the gastrointestinal tract and the thickness of the abdominal walls will cause difficulty in

displaying the ureter. Only for lean people, and when the gastrointestinal tract is without flatulence, the examination is done on both sides of the lumbar vertebra along the abdominal aorta and on the left and right sides of the inferior vena cava. The lower segment of the ureter is connected to the urinary bladder. When the urinary bladder is filled, its distal segment will be displayed on both sides of the trigone at the posterior wall of the urinary bladder. Usually, after revealing the male prostate (or seminal vesicle) or female uterine cervix, the sound beam is made to incline upwards, then the urinary bladder trigone will be displayed. The ureteral orifice can be found by using echogenic dots or cloudy echoes, produced by spurting urine at the ureteral orifice, as indicators. The posterior external side of its continuity is the distal segment of the ureter. If this segment is dilated, a tubular echoless, dark area will be found at the posterior external side of the urinary bladder wall.

11.3. SONOGRAM OF A NORMAL URETER

Ultrasonic imaging cannot easily display a normal ureter. By making use of the renal pyramid and urinary bladder, the upper and lower ends may sometimes be found. By applying diuretics or the method of filling the urinary bladder, a walking, stick-like echoless dark area formed by the upper segment of the ureter with a dark area of the pyramid may be displayed. However, the middle and lower segments are still not displayable. Present on both sides of the posterior wall of the urinary trigone as a parallel, short, tubular, echoless dark strip is the lower end of the ureter, which sometimes protrudes a little into the urinary bladder.

11.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE URETER

11.4.1. Ureteral Stone

This is a common disease in China. It is one of the common causes of hematuria and renal colic, and often occurs at the three narrowing portions.

(a) Stone at the first narrowing portion
After examining from the back, trace downwards when the pyramidal dark area is displayed. Usually at about 5 cm below the funnel, at the lower end of the ureteral dark-strip echo, a strong echogenic round area accompanied by a acoustic shadow may be detected. The diameter is usually about 1 cm. However, sometimes the area is without the accompanying acoustic shadows (Figs. 11.2 and 11.3).

(b) Stone at the lower end of the ureter
At the portion where the ureter enters the bladder wall or its upper part, strong echogenic dots or a round area can be found, and it often causes the lower end of the ureter and bladder wall to bulge into the bladder. Here is the third narrowing portion for the stone (Fig. 11.4). Its posterior may or may not be accompanied by acoustic shadows.

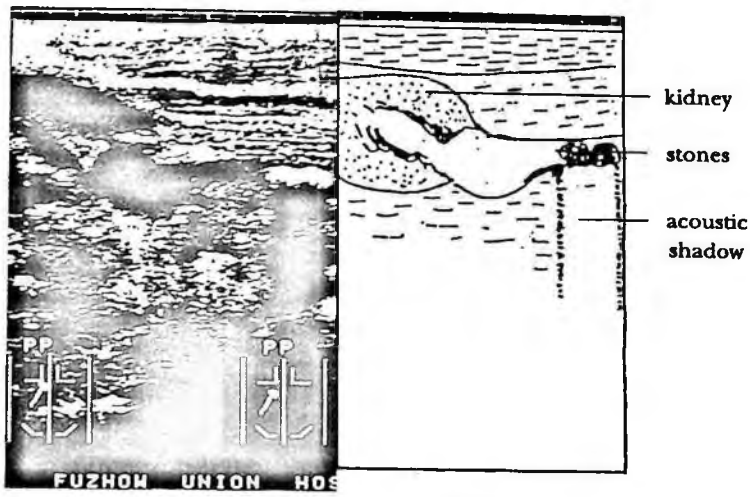

Fig. 11.2 Stone in the upper segment of the ureter.

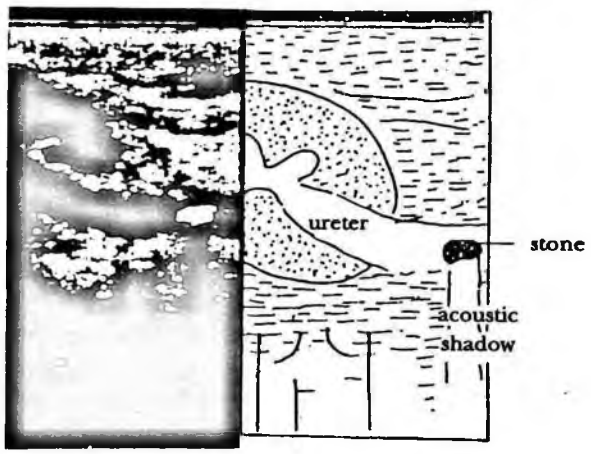

Fig. 11.3 Stone in the upper segment of the ureter.

(c) Stone at the second narrowing portion
A stone in the middle and lower segments of the ureter is often obstructed from view by the gastrointestinal gas and the bones behind, and is therefore hard to display. It is usually examined from the abdominal side where a fixed, strong, echogenic round area can be found. However, it must be differentiated from intestinal gas and calcified lymph nodes. Strong echoes are changed greatly in gas and calcified lymph nodes, but the strong echo of the stone is rather stable, with a dilated ureteral dark area in front.

11.4.2. Congenital Ureteral Cyst

It is commonly seen at the lower end of the ureter. At the posterior lateral wall of the vesical trigone, one can find a round echoless dark area. The cyst is usually unilateral, but it may

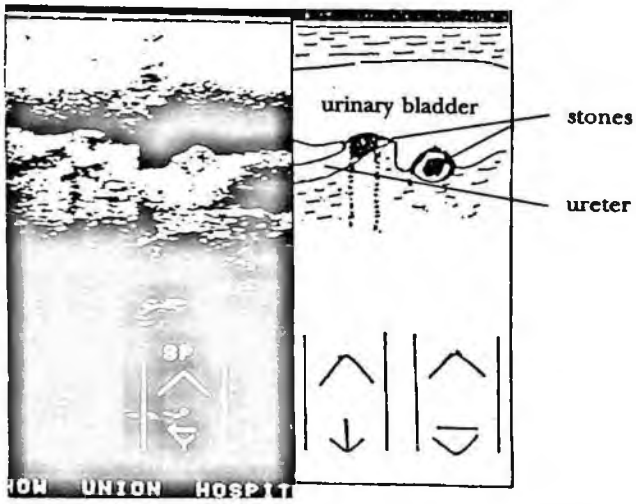

Fig. 11.4 Stone at the lower segment of the ureter.

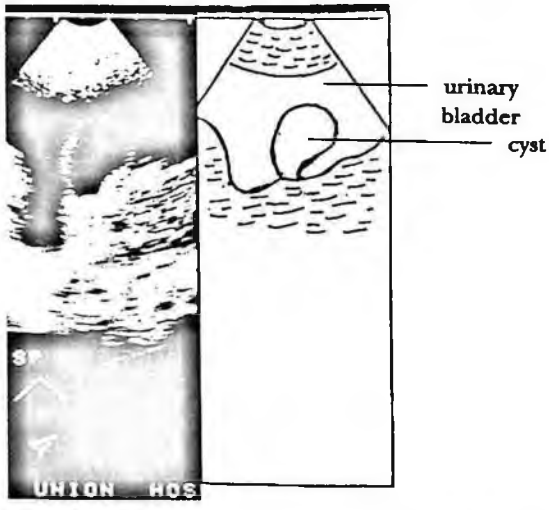

Fig. 11.5 Congential cyst at the lower end of the ureter.

also be bilateral and with varying sizes. It may change with the cycle of spurting urine by the ureter (Fig. 11.5). Sometimes, a gigantic, long, oval cyst appears in the middle and upper segments (Fig. 11.6).

11.4.3. Hydro-ureter

Blockage of the lower urinary tract may induce hydro-ureter and hydronephrosis. Usually it occurs bilaterally. The middle and later stages of pregnancy are examples of physiological causes, while pathological causes is often seen in hypertrophy of the prostage, tumor of

Fig. 11.6 Gigantic congenital cyst in the middle and upper segments of the ureter.

the urinary bladder or prostate, and tumor in the pelvic cavity. Unilateral hydro-ureter is often due to stones, tuberculosis, obstruction by tumors, or oppression by tumors in the abdominal cavity. It may also be due to congenital diseases such as congenital gigantic ureteral deformity.

Sonographic expressions such as a strip-like echoless area can be found along the ureter; cystic dilatation is usually presented. It is also accompanied by signs of various degree of hydronephrosis, and hydronephrosis is connected to the upper segment of the ureter, forming pipe-like echoes (Fig. 11.7).

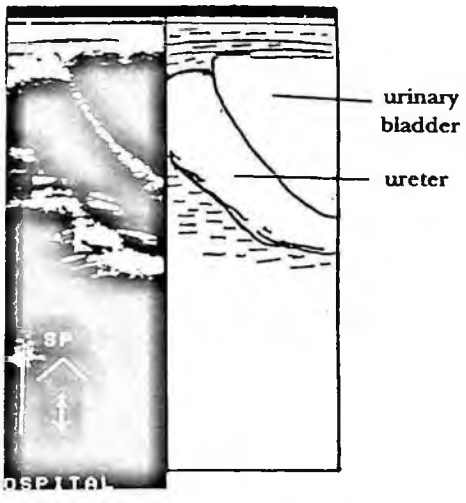

Fig. 11.7 Dilatation of the hydro-ureter.

11.4.4. Ureteral Tumor

The primary tumor of the ureter is seldom seen. Mostly, secondary tumors are seen in the pelvic cavity and other organs. The sonographic expressions are obstruction to the ureter, dilation, and fluid accumulation at its upper end presenting an echoless dark strip. The substantial echo is where the dark strip is interrupted. It is irregular, the boundary is usually unclear and its posterior is without any acoustic shadow (Fig. 11.8).

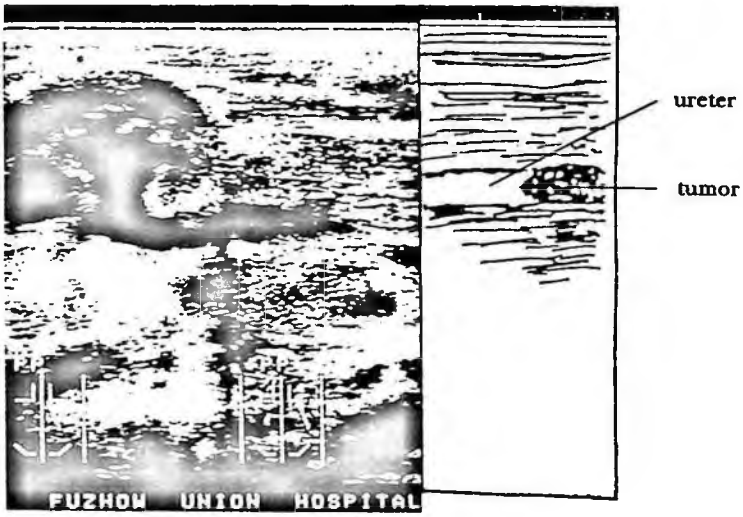

Fig. 11.8 Ureteral tumor.

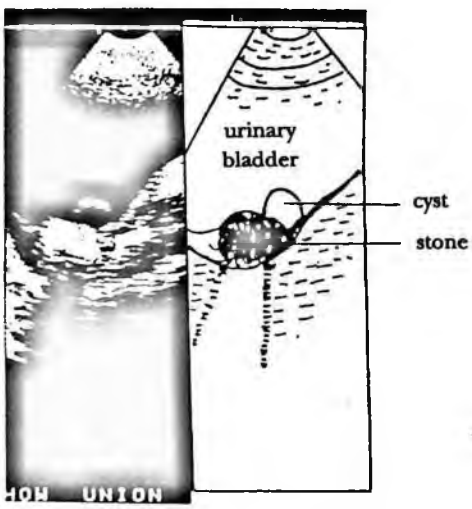

Fig. 11.9 Bilateral ureteral cyst. One among them is accompanied by a stone.

11.4.5. Congenital Deformities of the Ureter

The commonly seen deformities are the congenital ureteral cyst, duplicate ureter deformity, and congenital gigantic ureter.

A duplicate ureter is often accompanied by a duplicate pelvis. It is divided into complete and incomplete. The complete one has a separate opening to the urinary bladder. The incomplete one has the duplicate ureter joining into one before entering the urinary bladder. The sonogram shows two ureteral dark bands at the posterior lateral wall of the vesical trigone. Changes in the double pelvis are often found.

Congenital gigantic ureteral deformity is often accompanied by deformity in both the kidney and pelvis. The sonogram shows dilatation and increase in the thickness of the whole ureter, the thickness is variable, marked stenosis is found at the upper joining funnel of the pelvis and at the lower end where it enters the urinary bladder wall. Usually, it is a bilateral deformity. The echoless dark area is found at the vesical trigone. This disease should be differentiated from hydronephrosis and the accumulation of fluid due to obstruction in the ureter. The latter often shows a shrinking phenomenon, or signs of obstruction due to the oppression of the renal parenchyma (Fig. 11.9).

Chapter 12

Ultrasonic Imaging Diagnosis of the Diseases of the Urinary Bladder

Lin Liwu, Zhong Xinhua

The urinary bladder is a hollow organ filled with urine. It has fairly good sonolucence and forms marked interface echoes with the urinary bladder wall. Therefore, ultrasonic imaging of the urinary bladder can not only display the anatomic structure of the bladder clearly and understand the condition of the lesion, but the functional situation can also be observed. At the same time, it serves as a fairly good echolucent window for ultrasonic examination of the uterine annex and viscera in the pelvic cavity. Nowadays, vesical ultrasonic examination has been popularly applied in clinical diagnosis to compensate, and overcome, the limitations and defects of cystoscopy and cystoradiography. It has become the top choice of diagnostic approach for urinary bladder diseases.

12.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE URINARY BLADDER

A normal urinary bladder is a cone-like muscular sac. An adult's bladder is the bony pelvis posteroinferior to the pubic symphysis. The pointed end facing anteriorly upwards is called the apex of the bladder, the bulging portion facing posterioinferiorly is the base of the bladder, and the middle part is the body of the bladder. The pubic symphysis is attached to the bladder's anterior. In males, the bladder's poteroinferior is in contact with the seminal vesicle gland, the prostate, spermatic cord and rectum. In females, it is near the vagina and the uterine cervix. The apex and posterior wall of the bladder are covered by the peritoneum (Figs. 12.1 and 12.2).

The bladder wall consists of the mucous, muscular and serous membrane. There is a trigone at its base, the pointed end faces inferoanteriorly, and moving on would be the internal orifice of urethra. Finally, the two lateral angles represent the opening to the ureter. The muscle of the bladder is intricate and complex, and is called the puborescial muscle. The vesical internal sphincter is at the junction of the urethra and the bladder.

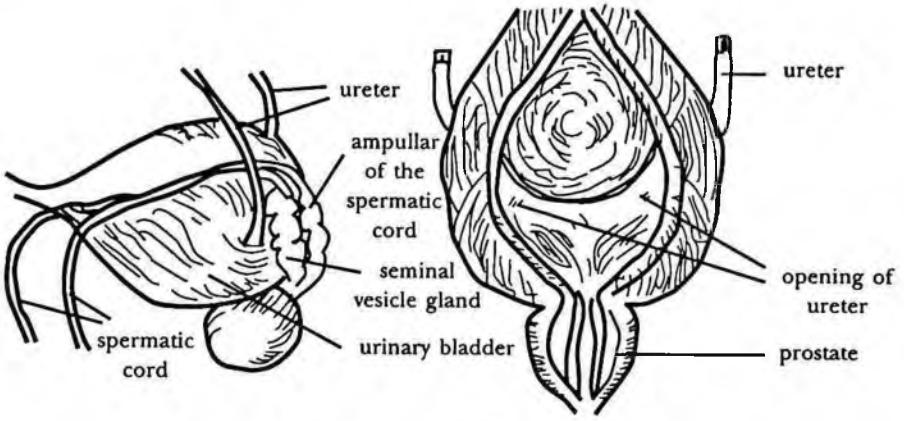

Fig. 12.1 Anatomy of the urinary bladder.

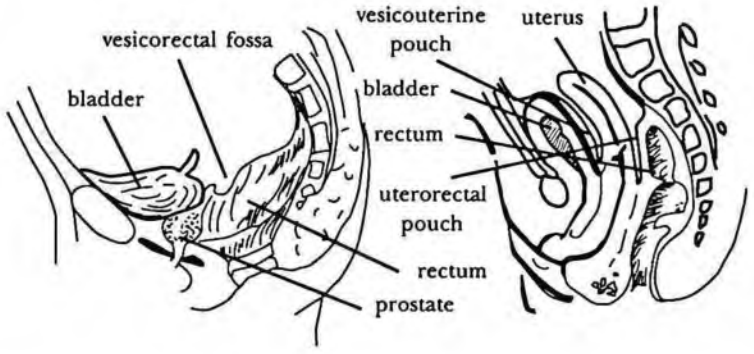

Fig. 12.2 Anatomic positions of the male and female bladder, with the surrounding organs.

Along with the increase and decrease in the amount of urine, the volume of the bladder is adjustable. In normal adults, the average volume is about 350–500 ml. The bladder muscle of an old man is relaxed, and the volume is increased. When cystitis or tuberculosis of the bladder occurs, the volume will be markedly decreased to below 200 ml, as big as only a ping pong ball. When retention of urine occurs, the volume of the bladder may even reach 1000–2000 ml, or even more.

An adult's bladder is within the pelvic cavity when it is emptied. When it is full of urine, its apex may reach the pubic symphysis, and it can be more easily displayed by ultrasound.

12.2. METHOD OF ULTRASONIC IMAGING EXAMINATION OF THE BLADDER

12.2.1. Conditions of the Apparatus

Different apparatus is selected according to the route of examination. For example, for a routine examination above the pubis, the linear array or sector real-time ultrasound

apparatus installed with a intraurethral probe is used. If examination is through the rectum, the apparatus should be installed with a transrectal probe. The frequency of the probe is usually 3.0–3.5 MHz, but for children a 5 MHz probe may be used.

12.2.2. Preparation Done by the Patient

When examining above the pubis, the bladder should be moderately-filled. But when examining through the rectum, the enema must be cleared prior to the examination.

12.2.3. Method of Examination

12.2.3.1. *Examination Above the Pubis*

The patient assumes the supine position and thoroughly exposes the lower abdomen. Place the probe superior to the pubis, take a serial longitudinal-section and cross-section. When the examination is done for the trigone or prostate, the probe is placed transversely above the pubis. Then moving the probe up and down, turn the plane of the sound beam laterally, gradually from pointing at the posterior wall of the bladder to the posteroinferior of the prostate. A cross-sectional image of the trigone and the lower end of the ureter or prostate will be obtained. By using sector scanning, the relation between the prostate and bladder will be displayed.

12.2.3.2. *Examination Through the Urethra*

After micturation, the patient assumes the lithotomy position and undergoes strict local sterilization and anesthesia. The urethral probe is then inserted into the bladder according to the manipulation process, and the bladder is properly filled. A 360° scanning may be conducted sequentially to examine every section inside the bladder.

12.2.3.3. *Examination Through the Rectum*

After cleaning the enema, the transrectal probe is capped with a rubber cover and lubricated with oil, then inserted through the anus. After filling the rubber cover with water, let the probe turn 360° to get a cross-sectional image of the base of the pelvis. By moving the probe up and down, a serial cross-sectional image of the bladder and prostate will be obtained. This method of examination is practical mainly for the examination of the prostate.

12.3. SONOGRAM OF A NORMAL BLADDER

The sonogram of the bladder varys with different routes of examination and the degree of the filling of the bladder.

12.3.1. Sonogram of the Examination Through the Abdominal Wall

The sonographic expression when the bladder is filled:

(a) The bladder is a flatly round or somewhat rectangular liquified area, which is surrounded by a bladder wall with strong echoes, presenting a complete light circle. Its thickness is about 3 mm, and it is greately changed by the degree of filling.
(b) The bladder wall is smooth, there is an enhancement effect at its posterior.
(c) The lower end of the ureter can be found at the posterior lateral wall of the trigone.
(d) During the evacuation, the bladder constricts and become irregular or has echogenic dots attached, which are actually the echoes of the folded wall of the mucous membrane.
(e) Behind the bladder of males is the intestinal tract, and surrounding the root of the urethra at the deep part of the pedal end is the prostate. In females, it is the uterus and the cross-section of the anus.

12.3.2. Sonogram of the Examination Through the Urethra

The centre of the sonogram is a round light circle (that is the probe), surrounding the light circle is the liquified dark area, and its outer circle is the smooth bladder wall.

12.3.3. Measurement of the Volume of the Bladder and Residual Urine

The volume of the bladder varies greatly with the degree of filling. Measuring the volume of the bladder is only done with the measurement of residual urine. Presently, the sonogram of the examination through the abdominal wall is used for the measurement. The calculation formulae is:

(a) Bladder volume (V) = $4/3\pi(r_1 \cdot r_2 \cdot r_3)$
(here r_1, r_2, r_3 are the radius of the length, width, and thickness, respectively),
(b) Bladder volume (V) = $\mathbf{K}(\mathbf{L} \cdot \mathbf{D} \cdot \mathbf{W})$
(here **K** is constant, **L**, **D**, **W** are the diameter of the length, width, and thickness, respectively),
(c) Bladder volume (V) = 5**PH** (Holmes method)
(here **P** is the maximum surface area of the cross-section, **H** is the distance from the upper margin to the apex of the bladder revealed longitudinally).

In the above three methods, formula (b) is more convenient, but poorer in accuracy. The constant used varies greatly. When measuring volume of the bladder, the degree of filling of the bladder is judged by proper intention of micturation. Measurements of the residual urine are judged by the dark area of the residual urine in the bladder after natural micturation by force, subjectively. During the examination, the probe should be perpendicular to the abdominal wall. As many measurements are taken as possible, and the average value is used. It should be noted that bladder volume measured by the sonogram has a definite disparity with the actual volume. Holmes applied the above method on 31 normal people, the average error that resulted was 18.7%, and the average error for 26 people was 24.5%. The minimum error was 0.5% and 0.7%, respectively, while maximum error was 48% and 72.8%, respectively.

12.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE BLADDER

12.4.1. Bladder Tumor

12.4.1.1. *Clinic and Pathology*

The bladder tumor is a tumor with the highest incidence in the urogenital system. The most commonly seen is the transitional epithelioapilloma, occuring in about 90% of bladder carcinoma. It often occurs at the trigone near the urteral orifice. It is mostly papilla- or cauliflower-like, with a pedicle, occuring singly or in multiples. Its size varies, with the diameter varying from several millimeters to several centimeters. Other malignant tumors like squamous epithelioma, adenoma and sarcoma, occupy only a small percentage. The main benign tumors of the bladder are papilloma, adenoma, and pheochromocytoma.

12.4.1.2. *Sonographic Expression*

(a) In the dark area of the bladder, particularly on one side of the trigone, one may find an entity with low-level echoes, or a hyperechogenic mass of echo enhancement (Figs. 12.3 and 12.4). Most of them present a papilla or cauliflower form (Fig. 12.5).
(b) The expression of the bladder wall where the tumor is attached to varies. If the bladder wall is still intact, bright, and without any signs of interruption, it means that the tumor has not yet infiltrated the muscular layer (Fig. 12.6). If the light band of the bladder wall is not distinct, and the continuity is interrupted, with signs of disorder, irregularity, or defect — all these mean that the tumor has already infilitrated the muscular layer (Figs. 12.7 and 12.8).
(c) Tumors with pedicles will float with any changes in the body position.

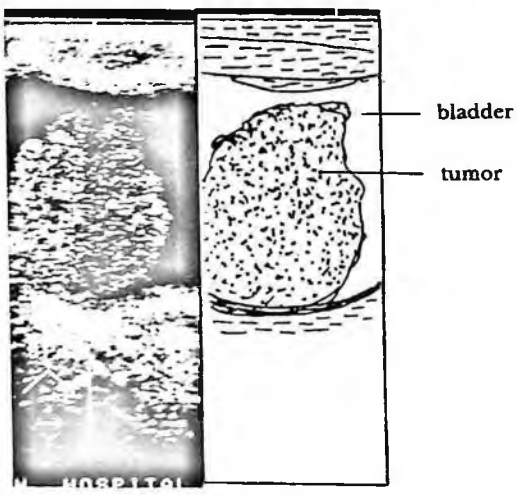

Fig. 12.3 Giant carcinoma inside the bladder presenting cauliflower-like changes.

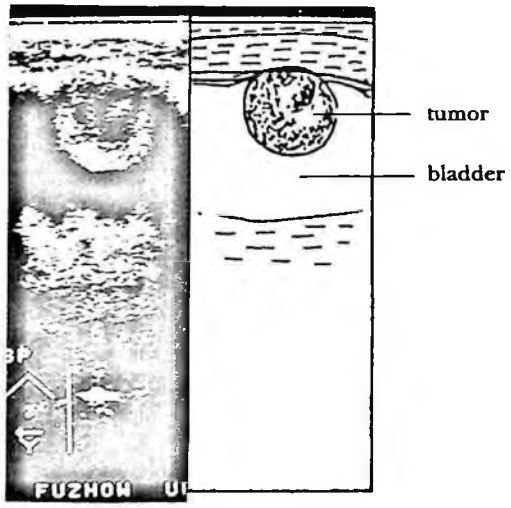

Fig. 12.4 Tumor at the anterior wall of the bladder (adenoma) wall is smooth.

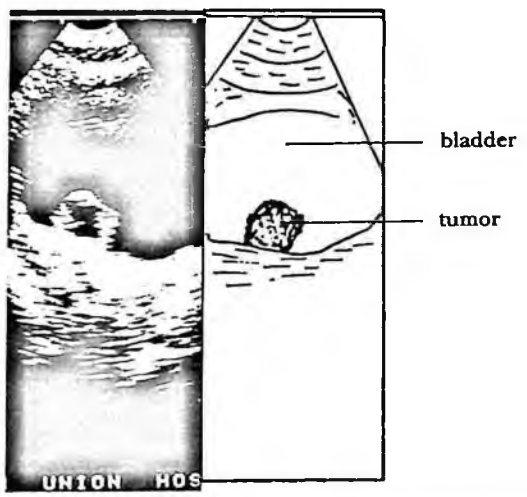

Fig. 12.5 Papillocarcinoma of the posterior wall of the bladder.

12.4.1.3. *Differential Diagnosis of the Sonogram of a Bladder Tumor*

(a) Blood Clot in the Bladder
The blood clot is without a continued based and pedicle, and will move distinctively with changes of the body position. The bladder wall is smooth, and the hyperechogenic mass moves to the anterior wall of the bladder in the knee–chest position. Therefore, a blood clot can be differentiated from the tumor (Fig. 12.9).

(b) Bladder stone
The bladder stone, especially a stone with no strong echoes, is easily confused with a tumor. A tumor with a pedicle will produce moving variations of the echogenic mass with

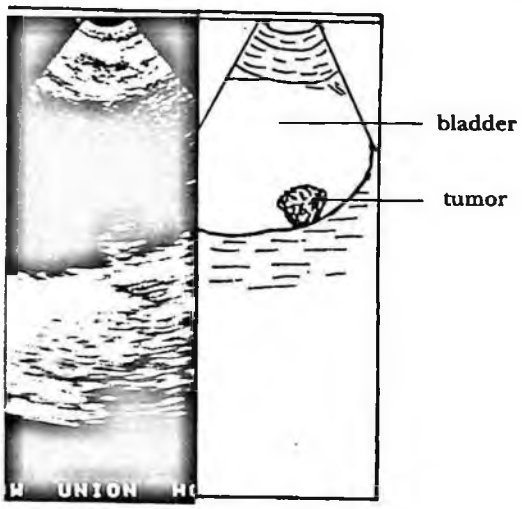

Fig. 12.6 Bladder tumor without infiltration of the muscular layer.

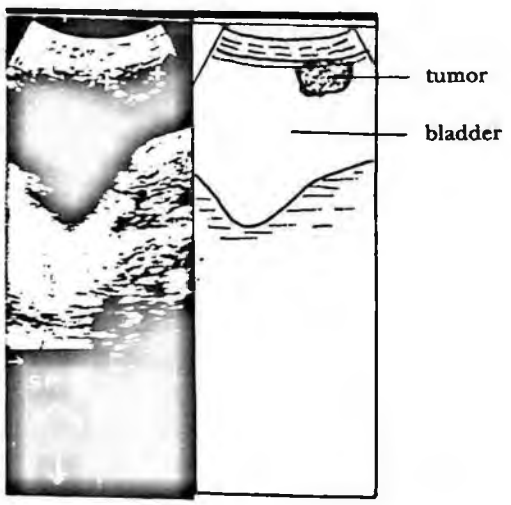

Fig. 12.7 Tumor of the anterior wall of the bladder infiltrates the muscular layer.

any changes in the body position. But the possiblity of moving the stone is bigger, and there is no connection with the bladder wall. According to the features of the sonogram, the majority can be differentiated.

(c) A tumor of the anterior wall of the bladder should be differentiated from the secondary echo of the abdominal wall

In general, the tumor of the bladder will have a rather clear boundary, and it will be clearly displayed by taking multiple sections or by changing the body positions, while the secondary echo will disappear with any changes in the direction of the examination or modulation of the gain. Also it is without a clear boundary (Figs. 12.10 and 12.11).

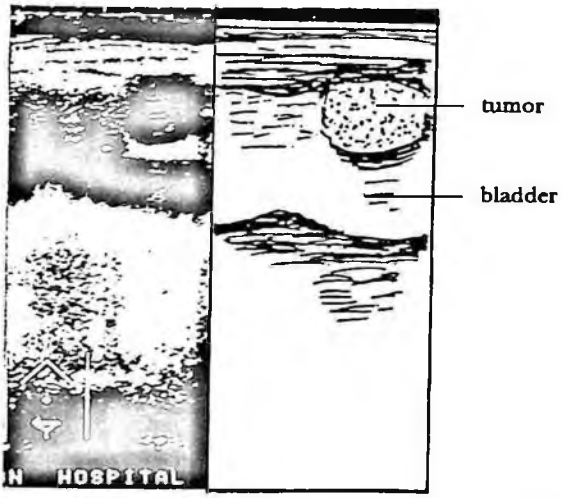

Fig. 12.8 Tumor of the anterior wall of the baldder infiltrates the muscular layer.

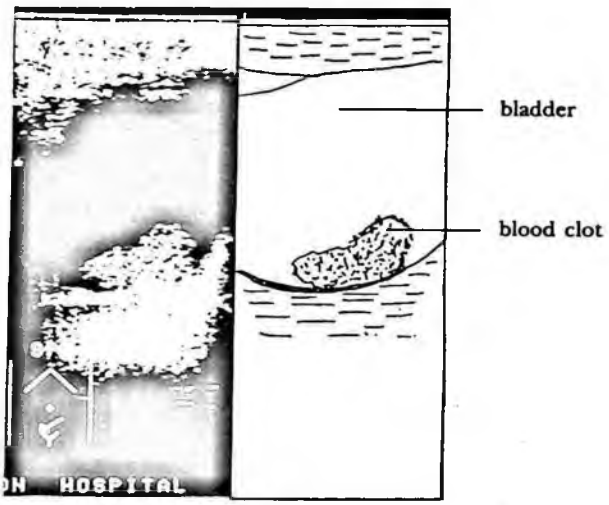

Fig. 12.9 Blood clot in the urinary bladder can move with changes in the body position.

12.4.2. Stone in the Bladder

12.4.2.1. *Clinic and Pathology*

Due to the obstruction of the lower urinary tract, hypertrophy of the prostate in an elderly person particularly, is easily accompanied by bladder stones. In addition, repeated infection of the bladder diverticulum and foregin bodies in the bladder will produce stones. About 16% of bladder stones are formed when stones in the kidney or ureter drop down. The size of the stone varies, they can be as small as a sand particle, or up to several centimeters large. The majority of the patients with bladder stones are male, the females occupy only about 5%. Clinically, the common expressions are severe pain during micturation, increase in the frequency of micturation, interruption of the urine stream, pyuria, and hematuria.

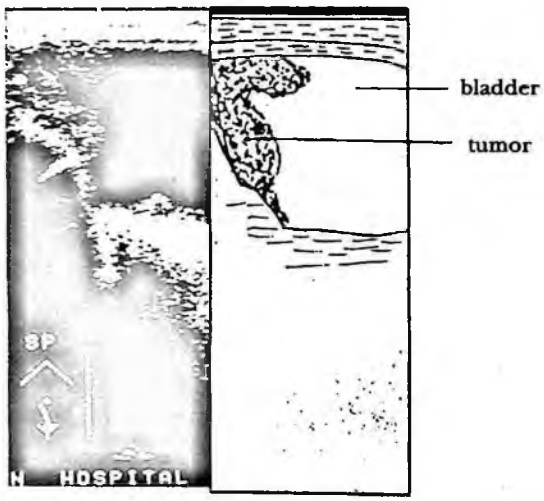

Fig. 12.10 Tumor of the anterior wall of the bladder. The bladder undergoes localized irregular thicknening.

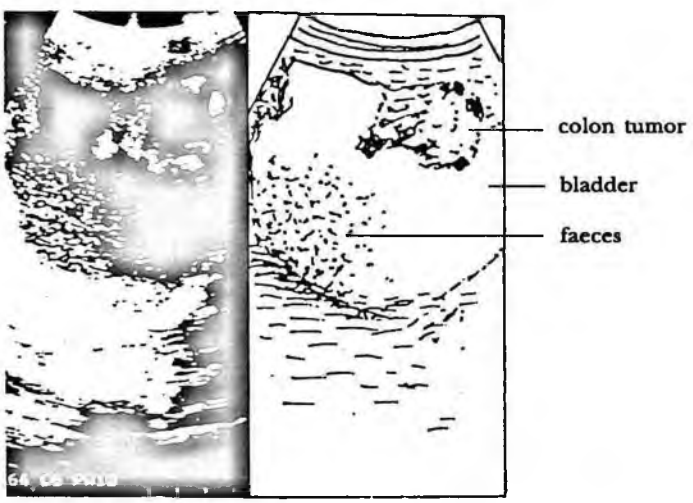

Fig. 12.11 Colon tumor invades the urinary bladder, faeces is seen in the urinary bladder.

12.4.2.2. *Sonographic Expression*

(a) For a stone with a compact structure, the echo is markedly increased, with marked acoustic shadows at its back (Fig. 12.12).
(b) For a stone with a loose structure, the echo is of medium intensity, with weak or no marked acoustic shadows at its back, but the structure of the stone is displayed clearly.
(c) The mobility of the bladder stone is like a lamp hanging on the anterior wall of the bladder, presenting pendulum-like movements as body position is changed.
(d) The stone at the lower end of the ureter is usually fixed at the postero-exterior superior part of the diseased trigone. At the same time, a dark band of the dilated ureter may be found.

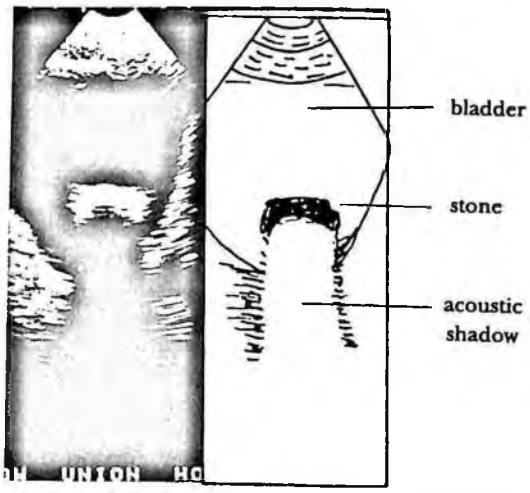

Fig. 12.12 Invasion of the bladder by carcinoma of the large intestine, a gas echo is found in irregular mass.

Small, sandy stones in the bladder are not easily found, hence, one should include the clinical expressions for careful identification.

12.4.3. Foreign Bodies in the Bladder

There are many kinds of foreign bodies in the bladder. Foreign bodies not transparent to x-ray, such as hair clips and steel beads, can be accurately diagnosed by x-ray, but x-ray-transparent foreign bodies, like plastic atricles and wax pieces, are not easily detected by x-ray examinations. Ultrasonic imaging can not only examine all sorts of foreign bodies and hemorrhage inside the bladder, it can also accurately identify the nature of the foreign bodies by the form displayed.

The sonographic expression of the foreign bodies varies with the nature of the foreign bodies. Abnormal echo masses, tubular sections, light circles or a light band identical to the section of the foreign bodies, may appear. Abnormal echoes are separated from the bladder wall and have a definite motility. They vary their positions with changes in body position. The sonogram is often complicated with sonographic changes related to injury and infection of the bladder.

12.4.4. Bladder Diverticulum and Other Deformities of the Bladder

12.4.4.1. *Clinic and Pathology*

There are two kinds of bladder diverticulum — the congenital and acquired diverticulum. An acquired bladder diverticulum is often due to the obstruction of the lower urinary tract. It is often complicated with bladder stones and hypertrophy of the prostate. The wall of the diverticulum has only transitional epithelium and fibrous tissues, with no muscular fibres. A bladder diverticulum may occur singly or in multiples, with great changes in size, and it

usually occurs at two sides of the bladder base. Often, the clinical expressions are a continuous urinary tract infection or ending pyuria. If there are complications of bladder stone, there will be clinical expressions of the bladder stone.

12.4.4.2. *Sonographic Expressions*

(a) At the lateral side, posterior and superior of the bladder, an echoless dark area without a definite form may be found. Its boundary is still regular, presenting echo light bands similar to the bladder wall. The internal echolucence is similar to the internal echo of the bladder. Searching carefully, one can find a cleft linking the dark area with the bladder. Clefts are different in size and there is an enhancement of echo at both ends (Fig. 12.13). The size of the echoless dark area will change with the degree of filling of the bladder.

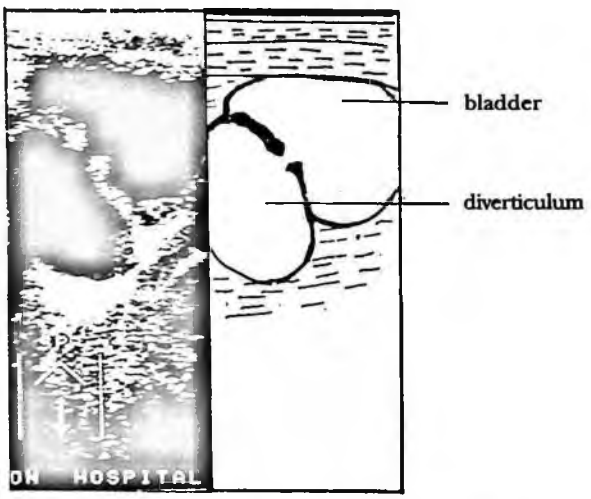

Fig. 12.13 Bladder diverticulum.

(b) The sonogram changes when there are complications with the bladder stones.
(c) It should be noted that the above-mentioned condition must be differentiated from the congential ureteral cysts or the cyst in the pelvic cavity. The ureteral cyst is located at the posterolateral wall of the trigone. Its size shows periodical changes with the release of urine. The cyst in the pelvic cavity has a thin and smooth wall. The internal sonolucence is fairly good, and its size has no relation with the filling of the bladder. Other deformities of the bladder, such as a duplicate bladder and absence of the bladder, is seldom seen clinically. By using ultrasonic imaging, they are easily diagnosed.

12.4.5. Bladder Tuberculosis

Renal tuberculosis is often the cause of bladder tuberculosis. There are no marked sonographic changes in the early stages. When an extensive lesion causes the contracture of the bladder, the volume of the bladder will become contracted and fixed. Even after drinking

a large amount of water, the change in the dark area of the bladder is not great. In addition, the wall of the bladder is markedly thickened, and the echoes are enhanced. Calcified strong echogenic dots may also be found. If the lesion invades the ureteral orifice of the trigone, sonographic changes of hydronephrosis will be displayed.

12.4.6. Chronic Cystitis

Clinically, the common expression of chronic cystitis is a repeated appearance of the symptoms of bladder irritation, such as an increase in the frequency and urgency of urination. Thus, it is mostly due to bladder stones or repeated infections, and it often coexists with stenosis of the urethra since both have effects on each other. It often develops secondarily after diverticulum.

Sonographic expression: the internal margin of the thickened bladder wall may reveal coarse echoes of the trabeculae. Its coarseness and size are not identical, but the distribution is still even. Much precipitum may also be found inside the bladder. When the body position is changed, the precipitum may be found floating in the dark area of the bladder.

12.4.7. Retention of Urine

Clinically, retention of urine is commonly seen in paralysis of the bladder, repression of urination, and other functional embarrassment of an organic obstruction due to injury, surgical anaesthesia, medication and chronic obstruction of urinary tract (such as hypertrophy of the prostate), which results in acute or chronic retention of urine in the bladder.

Sonographic expression: the volume of the bladder is markedly enlarged, and its outline is like a ball. The echo of the bladder wall is smooth and fine. In acute retention of urine, the bladder wall is thickened, the echo is enhanced, and sometimes incomplete echoes of the trabeculae may be found. In addition, the urethra of the trigone and the prostate portion present funnel-like changes. Also, various degree of the dilatation of the ureter and renal pelvis are often seen (Fig. 12.14).

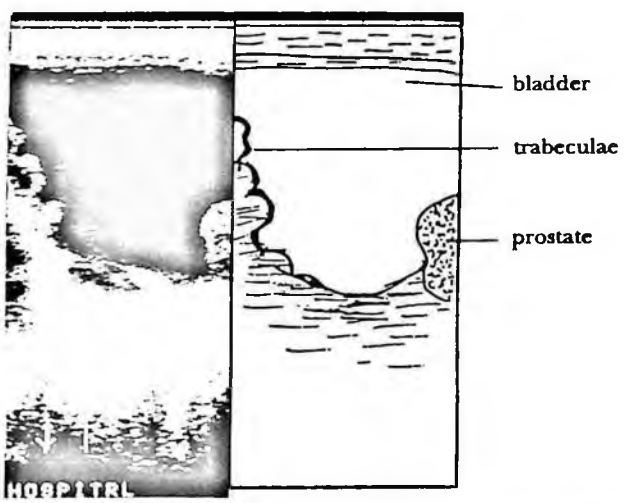

Fig. 12.14 Formation of trabeculae at the bladder wall in chronic retention of urine.

Chapter 13

Ultrasonic Imaging Diagnosis of the Diseases of the Prostate

Lin Liwu, Zhong Xinhua

Hypertrophy and tumors of the prostate are common diseases in the urinary system of the elderly. Real-time ultrasonic imaging process has a very important practical value in understanding the size of the prostate, the nature and extent of the lesion, and the relationship with the urinary bladder. Overcoming the defects of digital examination in the past for diagnosis, has greatly improved the rate of accuracy in diagnosing diseases of the prostate.

13.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE PROSTATE

The prostate is the largest auxillary parenchymal gland in the male genital system. It is unpaired and chestnut-shaped. It is located in the urethral prostate portion, at the lower end of the bladder, encircling that part of the urethra from the apex of bladder, down to the membranous portion of the urethra. The anterior is close to the inferior margin of the pubis and the posterior is the rectum. The urethra passes through the prostate, a shallow groove called the prostate groove is at the posterior median. There are five lobes in the prostate: anterior lobe, middle lobe, posterior lobe, left and right lateral lobes. The anterior lobe is very small. The middle lobe is also called the isthmus of the prostate, and is located at the posterior part of the urethra between the two lateral lobes and ejaculatory duct. It is wedge-shaped, presenting a wide top and narrow bottom. The two lateral lobes are the largest. Hyperplasia easily causes the retention of urine. The posterior lobe is in close contact with the rectum. During the digital examination per anum, it is easily felt and expresses less hypertrophy (Fig. 13.1).

The prostate consists of the gland, smooth muscles and connective tissues. There is a capsule on the surface, which is divided into three layers from the exterior to interior. The external layer composes of the vein and loose connective tissues, the middle layer is the fibrous sheath, and the internal layer is the muscular layer. It is considered by recent

anatomy, that it is more practical for the prostate to be divided into the periglandular area (also called the external gland) and central area (also called the internal gland).

There are seminal vesicles between the postero-inferior of the prostate and the rectum, one on the left and one on the right side. It is represented by a symmetrical dark area in the image, and the echo of the vesicle wall is clear.

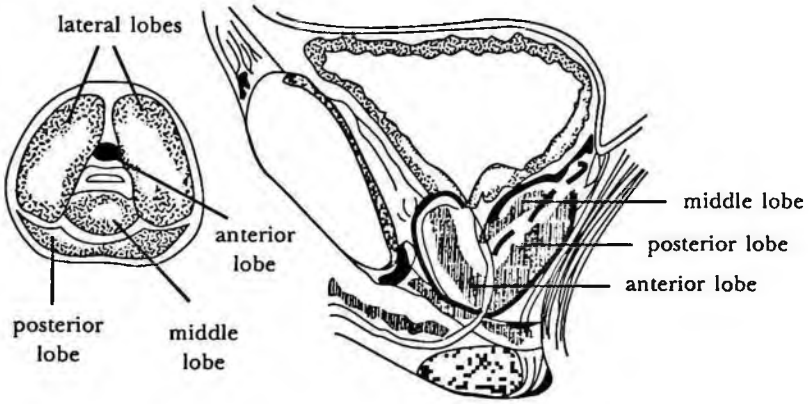

Fig. 13.1 Anatomic location of the prostate.

13.2. METHOD OF EXAMINATION

13.2.1. Condition of the Apparatus

Different apparatus is used according to the different routes of examination and different methods. For examination above the pubis through the abdomenal wall, real-time linear array or sector probe is mostly used, but the sector probe is more ideal. The frequency of the probe is 3–3.5 MHz. If examination is by the transrectal method, a special probe for the rectum is used. If examining through the perineum, a section probe should be applied. The frequency of the probe at 5 MHz is much better.

13.2.2. Preparation Done by the Patient

(a) When examining through the abdominal wall and perineum, the bladder should be kept moderately filled; if the bladder is fully filled, the prostate will be pushed to the posterior-inferior, which will not be favorable to imaging and should be avoided.
(b) When examining through the transrectum, defecation should be done prior to examination, cleansing the enema if necessary.

13.2.3. Method of Examination

13.2.3.1. *Examining Through the Abdominal Wall*

The patient is in the supine position. The abdominal wall and lower abdomen is thoroughly exposed. The probe placed on the upper margin of the pubic symphysis, and a transverse

section and longitudinal section is taken. Firstly, get the image of the transverse section of the bladder, then incline the sound beam plane of the probe towards the internal inferior of the pubis. The image of the cross-section of the prostate will be obtained right away, and the image's largest cross-section is measured. Rotate the probe 90°, the prostate will be obtained. When doing the longitudinal section, the probe is in close contact with the upper margin of the pubis and deeply pressed to allow the sound beam plane to pass through the inferior structure of the prostate. In general, when using the linear array probe, it is difficult to get a satisfactory image of the longitudinal section.

13.2.3.2. *Examining Through the Perineum*

Zhang Wu of Beijing Medical University in China has experienced success in this method. Using the sector ultrasonic scanner, the patient takes the side bending position at the bedside, exposing the buttocks, or he may also take the supine position, thoroughly exposing the perineum (the examination point of the posterior area is the anterior margin of the anus). The probe faces the pubic symphysis, to undergo longitudinal and oblique coronary section scanning. For the sake of obtaining a clearer sonogram of the prostate, the probe should be tightly pressed against the soft tissues of the perineum.

13.2.3.3. *Examining Through the Transrectum*

The probe is capped with an emulsion cover which is rubbed with paraffin oil. The probe is inserted into the anus slowly. After entering about 5–8 cm, clean water is instilled into the emulsion cover of the probe through a tube, then the examination can be done. Observing the cross-section of the prostate in front of the rectum is done by moving the probe up and down, in order to observe every part of the prostate. The probe is gradually taken out after the clean water inside the cover is drawn out fully.

13.3. SONOGRAM OF A NORMAL PROSTATE

13.3.1. Sonogram of the Examination Through the Abdominal Wall

The longitudinal section of the prostate is located postero-inferior to the bladder, it is in the shape of triangle. The internal is the echo of the parenchymal dark area with echoes deviating to the low level, the echogenic dots are fine and even. Sometimes, one may find rather strong linear strip echoes at its postero-inferior region. This is the echo of the posturethra depression. On the surface of the bladder is the internal orifice of the urethra. The morphology of the cross-section is flatly round or like a chestnut, with the base upwards and apex downwards. At the central part, urethral echoes can be detected (Fig. 13.2).

13.3.2. Sonogram of the Examination Through the Perineum

The prostate is located between the rectum and bladder. From the oblique coronary section the outlook of the prostate may be similar to a triangle with an obtuse margin, or an oval.

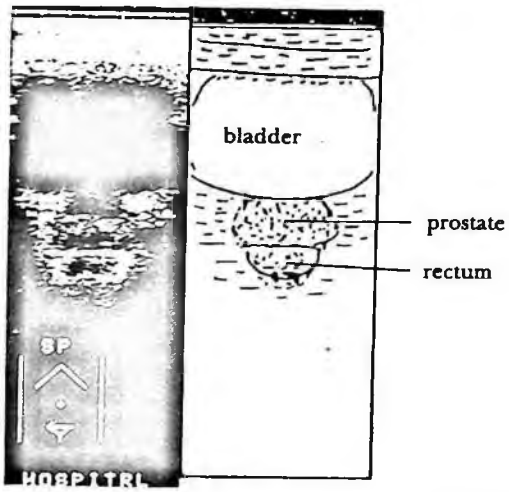

Fig. 13.2 A normal prostate (cross section through the abdominal wall).

The capsule is complete and clear and the two sides of the parenchyma are symmetrical. The internal gland is approximately round, with a rather weak echo. It is centrally located and lies close to the base of the bladder. The echo of the external gland is rather strong but even, presenting an iron-heel shape, and encircling the internal gland.

13.3.3. Measurements of the Prostate Size and the Normal Values

Due to the location of the prostate, it is difficult to get its accurate volume when examining from outside the body. At present, the majority of measurements are by its maximum transverse diameter and anteroposterior diameter. The superior and inferior oblique diameters should be examined through the abdominal wall using the section probe, or it may be examined through the perineum. The size of the prostate progressively increases with

Table 13.1. Ultrasonic Measurements of a Normal Prostate (cm)

	Examining Through the Abdominal Wall			Examining Through the Perineum	
	Transverse Diameter	**Antero-posterior Oblique**	**Superior-inferior Oblique Diameter**	**Perineum Transverse Diameter**	**Superior-inferior Oblique**
Zhang Wu	4.13 ± 0.62	2.75 ± 0.44	2.88 ± 0.52	4.49 ± 0.67	2.40 ± 0.44
Union Hospital (affiliated to Fujian Medical University)	4.20 ± 0.51	2.57 ± 0.37	2.75 ± 0.48		

the advancement of age, during which the variation in the anteroposterior diameter is more sensitive.

13.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE PROSTATE

3.4.1. Hyperplasia of the Prostate

13.4.1.1. *Clinic and Pathology*

Hyperplasia of the prostate is also called benign hypertrophy of the prostate. It is a common disease in elderly people. It is mostly the result of a disorder in the sex hormone with the advancement of age. The pathological changes mostly occur in the internal gland. Its main expressions are enlargement of the volume reaching to 2–4 times the normal size, often nodular; the gland inside the nodule may dilate into a cyst, and sometimes appear honey comb-shaped; its quality is hard with some elasticity, it may oppress the surrounding external glandular tissues and the posterior urethra. Most of the cases express hyperplasia of the two lateral lobes and may be accompanied by hyperplasia of the middle lobe at the same time. Minority of the cases show localized hyperplasia, revealing the hypertrophied middle lobe protruding into the bladder. The volume of the prostate with hyperplasia of multiple lobes is usually markedly enlarged. Clinically, it often presents increase in the frequency of micturation. In severe cases, it will cause retention of urine and hydronephrosis, finally leading to failure of the renal functions.

13.4.1.2. *Sonographic Expression*

It varies with different types of hyperplasia.

(a) The volume of the prostate is markedly enlarged; the main expressions are enlargement of the internal gland, and the external gland becomes thinner due to oppression, its outlook is regular.

(b) Abnormal morphology: it often shows a relatively marked increase in the anteroposterior diameter of the prostate. It loses its normal triangular shape, becoming round, its outline is rather complete, smooth, and the boundry between the internal and external gland is still clear (fig. 13.3).

(c) For a person with hyperplasia of the middle lobe of the prostate, the middle lobe may protrude into the bladder. Its outline is regular and the margin is smooth (Fig. 13.4). It should be differentiated from a bladder tumor (Fig. 13.5).

(d) Internal echoes of a hyperplastic prostate are somehow lower, but the echogenic dots are rather even. If complicated with stones and when it is calcified, scattered echogenic dots or echoes of hyperechogenic mass may be found at the interface of the internal and external glands. Its posterior may be accompanied by a perpendicular acoustic shadow.

(f) May be accompanied by thickening and roughness of the bladder wall, or sonographic changes of hydronephrosis.

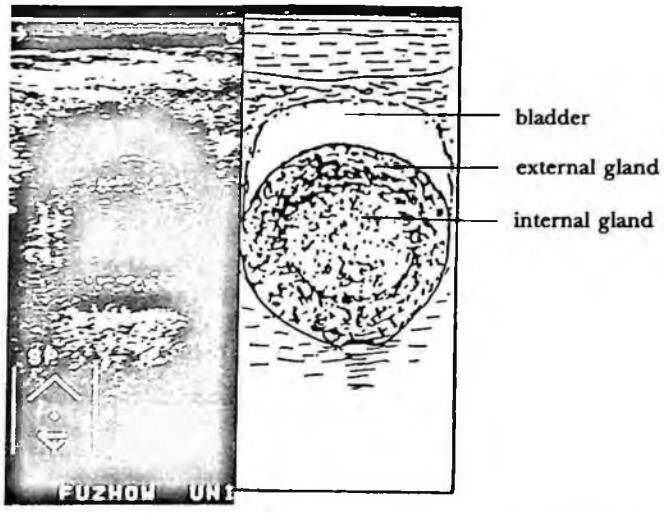

Fig. 13.3 Hyperplasic boundary between the internal and external gland is clear.

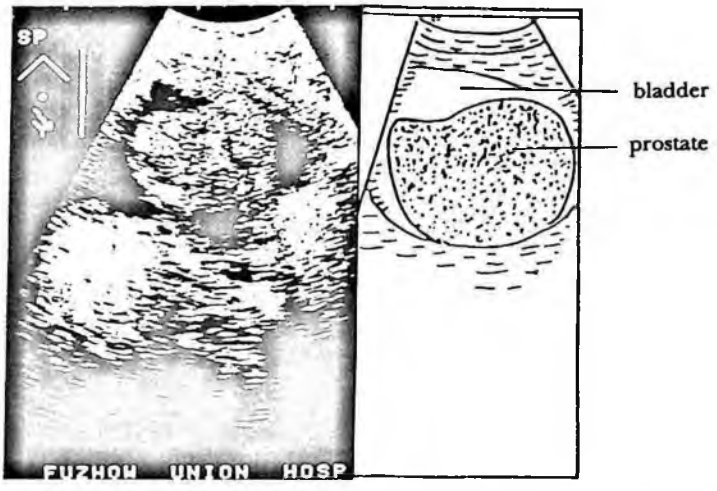

Fig. 13.4 Hyperplasia of the middle lobe of the prostate, protruding into the bladder.

13.4.2. Carcinoma of the Prostate

13.4.2.1. *Clinic and Pathology*

Carcinoma of the prostate is also a common disease in elderly men, about 50% develop on the foundation of benign hypertrophy of the prostate. The posterior lobe is commonly seen forming single or many small nodules. It is hard and gradually involves the major part, or whole part, of the prostate. The carcinoma may also protrude into the bladder and obstruct the urethra, resulting in hydronephrosis and retention of urine. It differs from the hyperplasia of the prostate by the easy occurrence of hematuria and all signs of metastasis of the carcinoma.

Fig. 13.5 Hyperplasia of the prostate, protruding into the bladder. The left figure shows the longitudinal section, the right figure shows the cross-section.

13.4.2.2. *Sonographic Expressions*

(a) Different degree of enlargement of the prostate, often non-symmetrical;
(b) Irregular morphology of the prostate, boundary echoes incomplete or without continuity;
(c) Internal echoes of the prostate are uneven. Irregular echogenic dots hyperechogenic mass, or a low-level echo area may appear. Those protruding into the bladder may cause the bright light wheel to appear (Fig. 13.6).
(d) Small tumorous nodules, mostly located in the external lobe, often oppress the internal gland, and may also protrude into the bladder.

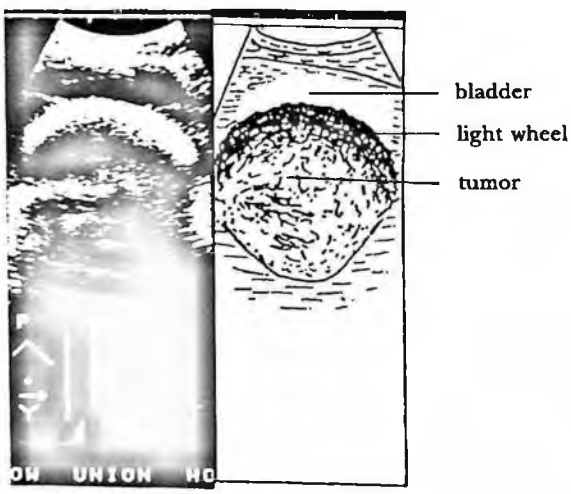

Fig. 13.6 Surface of the anterior side of the carcinoma of the prostate forming a "light wheel".

(e) Signs of metastasis of the tumor into the surrounding organs, such as the seminal vesicle and trigone.

13.4.3. Chronic Prostatitis

Chronic prostatitis often occurs in middle-age and young men. The volume of the prostate does not change much. The main clinical expressions are: the patient feels dull, there is an expanable pain in the perineum and superior part of the pubis; milky mucous fluid flows out of the urethra at the end of micturation or during defecation, and sometimes it may be accompanied by embarassement of the sexual functions. This disease often has a cause and effect relationship with urinary tract infection.

Sonographic expression: the changes in the sonogram of chronic prostatitus are irregular. Mild cases show no obvious changes. Typical cases may have various degree of enlargement, with the outline lacking regularity, uneven intensity of the internal echogenic dots, irregular distribution, and an unclear boundary between the internal and external gland.

13.4.4. Fibrosis of the Prostate

This disease is often seen in the elderly. The prostate shrinks due to fibrosis. Clinically, signs of obstruction of the urinary tract are found, and it is usually without hematuria.

Sonographic expression: the volume of the prostate decreases, echogenic dots increase in coarseness and are enhanced, distribution is markedly uneven and one may also find strong echogenic dots or a light band.

13.4.5. Stone of the Prostate

The stone of the prostate is often seen in middle-age men, usually co-existing with hyperplasia of the prostate. The predilective place for the stone is the interface between the internal and external gland, or close to the posterior urethra. Difficulty in micturation may be experienced.

Sonographic expression: inside the prostate, one may find a single or many echogenic dots or light hyperechogenic masses of strong echoes, the perpendicular acoustic shadow is at its posterior. The stone is usually found at the posterior half of the prostate and it is usually placed transversely.

13.4.6. Diverticulum and Cyst of the Prostate

Both are congenital diseases of the prostate and usually occur close to the bladder. In general, the clinical symptoms are not marked. When the diverticulum and cyst are fully-filled with fluid, there may be difficulty in micturation due to oppression of the urethra. In the sonogram, a round echoless dark area may be found inside the prostate. When the cyst becomes larger, the marginal parenchyma of the prostate is only a small portion. A large cyst may also be located at the margin of the gland.

Ultrasonic imaging has a rather high rate of diagnosis on diseases of the prostate. It can not only accurately measure the size of the prostate and overcome the inadequate digital examination in clinics, but may also observe clearly the nature and extent of the lesion in the middle and laternal lobes. It can dynamically observe the therapeutic effect and display the relationship between the prostate and its surrounding tissues.

Chapter 14

Ultrasonic Imaging Diagnosis of the Diseases of the Scrotum

Xue Ensheng

The scrotum is a superficial and small organ. In the past, diseases of the scrotum were mainly diagnosed according to the clinical symptoms and physical signs. When the scrotum is distinctly turgescent, palpation is always unsatisfactory. But the ultrasonograph can clearly display the structures in the scrotum. It has a comparatively high rate in diagnosing hydrocele testis, tumors, inflammation of the testis and epididymis, and enorchia. Color Dopple Sonography is a well-accepted method for evaluating abnormalities of the scrotum. The use of Color Dopple Sonography is especially important in the diagnosis of acute diseases and varicocele, allowing for evaluation of perfusion and morphology.

14.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE SCROTUM

The scrotum is a skinny pocket structure divided into two similar compartments by the septum of the scrotum. There is a testis, an epididymis and a spermatic cord in each hemiscrotum.

14.1.1. Testis

It is an solid ovoid organ. The size of each one on the left or right is 3–4 cm long, 2–2.5 cm thick and 2–3 cm wide. Each testis has two sides, inside and outside, and two ends, the upper and lower end. The testis has a tunica vaginalis testis around the smooth surface.

14.1.2. Epididymis

It is a long, flat organ of irregular thickness, consisting of the head, body and the tail. The head of the epididymis adheres to the apex of the testis, the body to the posterior outer margin, and the tail to the fundus. There is the tunica vaginalis testis at the side of the epididymis.

14.1.3. Spermatic Cord

It is a soft strip-like structure from the annulus inguinalis abdominalis, through the annulus inguinalis subcutaneus to the apex of the testis. Its external diameter is about 0.5 cm and it consists of a ductus deferens, an artery of the testis, and a plexus pampiniformis overcasted by the spermatic tunica vaginalis (Fig. 14.1).

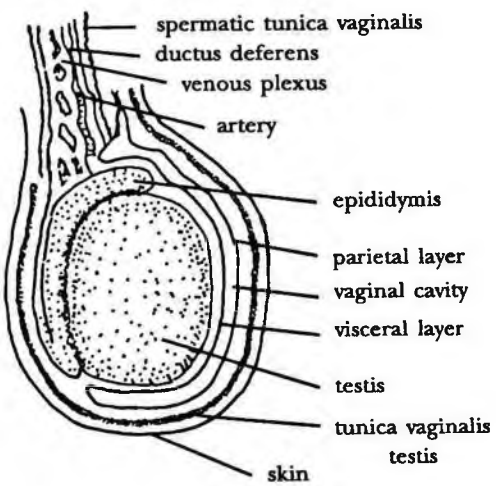

Fig. 14.1 Sketch map of the anatomy of the scrotum..

14.2. SCROTAL ULTRASOUND EXAMINATION METHODS

14.2.1. Equipment

The scrotal ultrasound examination is usually performed with a real-time Linear Array or Convex Array Scanner, while scrotal blood perfusion is by the Pulse Doppler and/or Color Doppler Sonography. The appropriate transducer frequencies are usually 5 MHz and 7.5 MHz.

14.2.2. Preparation

No preparation by the patient is required.

14.2.3. Examination Method

The patient lies in the supine position and exposes the cunnus. The transducer is placed directly on the scrotal skin. The scrotum should be scanned in both the longitudinal and transverse planes. When examining the enorchia, both the inguinal region and the retroperitoneal space should be carefully scanned.

14.3. SONOGRAM OF A NORMAL SCROTUM

The testis is approximately 3–4 cm by 2.5–3 cm by 2–2.5 cm in diameter. It is homogeneous in texture and has a smooth edge. A linear echogenic mediastinum is usually seen within the testis. The echogenicity of the epidiymis is similar to the testis. The body of the epididymis is not easily seen. The scrotal wall varies in thickness from 2–7 mm. The spermatic cord can be identified, it is approximately 5–10 mm in diamter, going up through the inguinal canal. Small tortuous spermatic veins, less than 2.0 mm in diameter, are found along the cord.

14.4. SONOGRAPHIC DIAGNOSIS OF DISEASES OF THE SCROTUM

14.4.1. Vaginal Hydrocele

14.4.1.1. *Clinic and Pathology*

Vaginal hydrocele is caused by congenital defects or diseases of the testes, epididymis and some other systems. The scrotum or the inguinal canal is swollen in the ovoid or round, smooth and elastic state. The vaginal hydrocele is graded into two pathologic types:

(a) The hydrocele testis
The fluid accumulates in the tunica vaginalis testis.
(b) The spermatic hydrocele
The fluid is found in the spermatic tunica vaginalis. It is an orange and serous fluid.

14.4.1.2. *Sonographic Expression*

(a) Hydrocele testis
There appears to be a fluid anechoic area surrounded by the testis in the enlarged scrotum (Fig. 14.2).
(b) Spermatic hydrocele
An ovoid fluid-filled anechoic mass is seen on the testis or in the inguinal canal (Fig. 14.3).

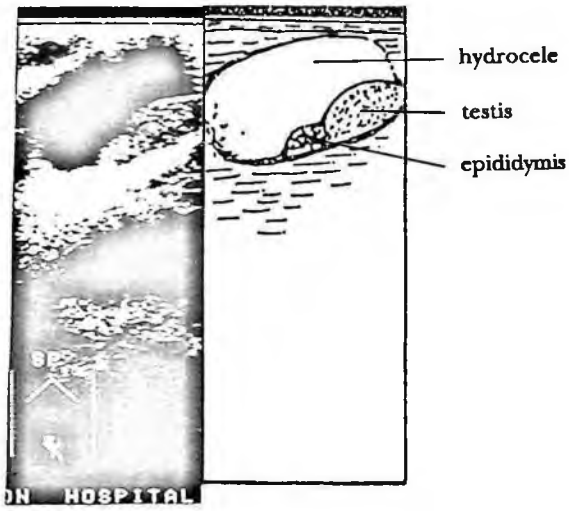

Fig. 14.2 Hydrocele testis.

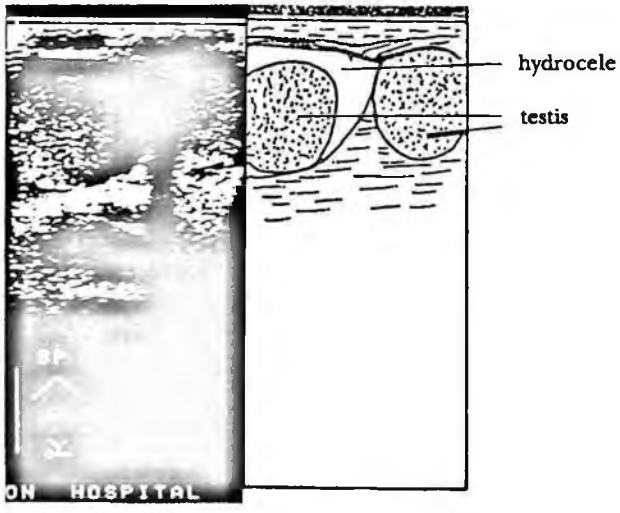

Fig. 14.3 Spermatic hydrocele.

(c) If vaginal hydrocele has no complications, then the testis and the epididymis will appear normal. If the hydrocele is accompanied by some intrascrotal diseases, the relative sonographic expressions can be seen in the scrotum.

(d) The hydrocele should be carefully differentiated from the spermatocele. The spermatocele always occurs in the head of the epididymis. As the cyst is huge, the nature of the fluid in the cyst (which is creamy) can be used to differentiate it from the hydrocele.

14.4.2. Orchioncus

14.4.2.1. *Clinic and Pathology*

The testis is enlarged, hard and rough, sometimes it is accompanied by a swollen pain. About 10% of the patients have fevers wtih redness and swelling of the scrotum. There are mainly three pathological types of orchioncus. These are semioma, teratocarcinoma and embryopathy. Seminoma is the most common type.

14.4.2.2. *Sonographic Expression*

The testis is enlarged locally or diffusely. Its surface can be smooth or rough. The tumor may appear hypoechoic, hyperechoic, homogeneous or mixed-echo. It may appear as a single mass or multitude. Seminoma mostly appears as a well-defined, homogeneous hypoechoic mass, while teratocarcinoma appears as a well-defined, mixed-echo mass with echo-density and fluid anecho in it. Multitude irregular fluid-echo area can usually be seen in the embryopathy.

14.4.3. Cryptorchism

14.4.3.1. *Clinic and Pathology*

The patient usually has no trouble, except for feeling a slight pain in the affected region sometimes. According to the location of the testis, cryptorchism may be divided into two types: the inguen type and retroperitoneal type. The possibilty of cryptorchism canceration is higher than that of the normal testis (Fig. 14.4).

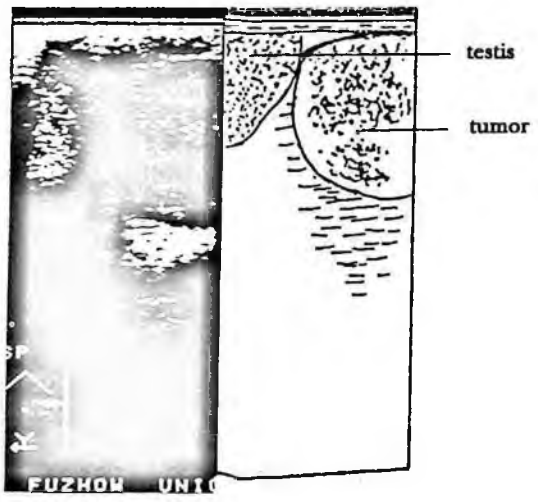

Fig. 14.4 Orchioncus

14.4.3.2. *Sonographic Expression*

There is no testis in the scrotum. It can be examined in the inguen or retroperitoneum. Although it is smaller than normal, it is smooth at the edge, homogeneous in texture and slightly less echo-dense than normal (Figs. 14.5 and 14.6).

There is a fluid anechoic area surrounding the testis if it is accompanied by hydrocele. If the testis is obviously enlarged, cancer must be suspected (Fig. 14.7). Cryptorchism should be carefully differentiated from lymph nodes or tumors.

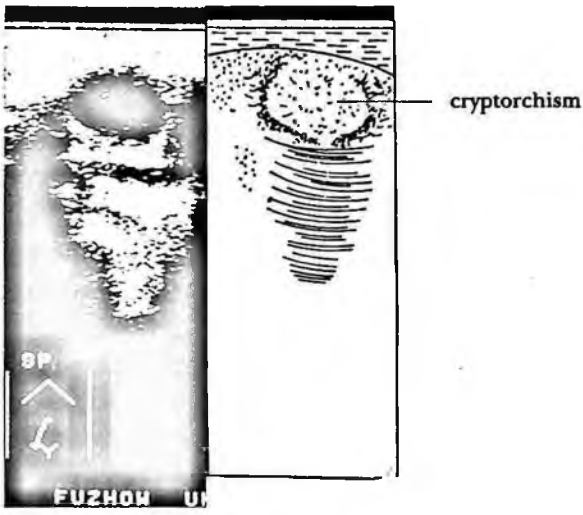

Fig. 14.5 Cryptorchism

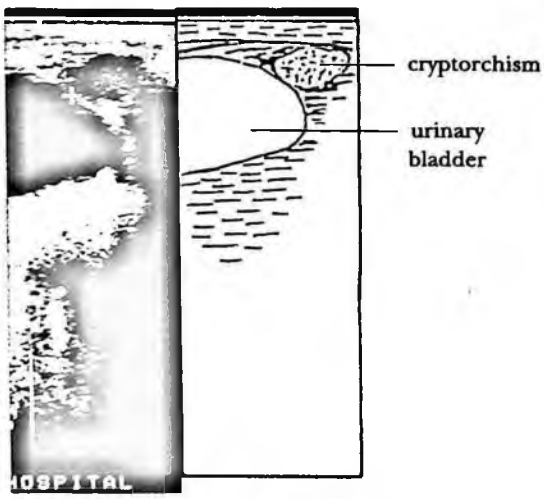

Fig. 14.6 Cryptorchism

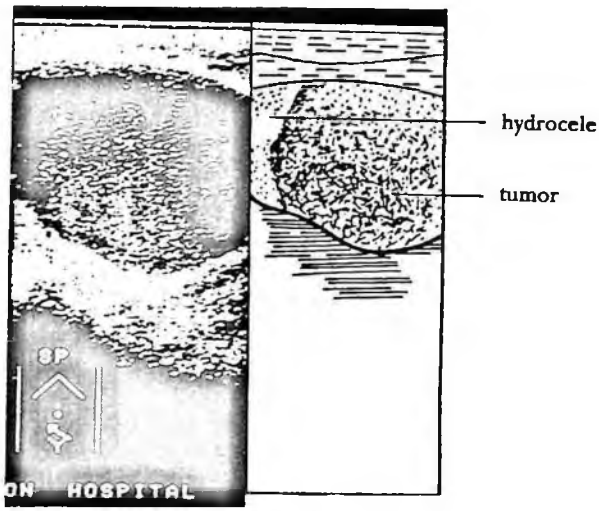

Fig. 14.7 Cryptorchism canceration. The testis is markedly enlarged.

14.4.4. Acute Orchiepididymitis

14.4.4.1. *Clinic and Pathology*

Acute orchiepididymitis is often secondary to urinary tract infection. There is flushing, swelling and pain in the scrotum, sometimes accompanied by a fever.

14.4.4.2. *Sonographic Expression*

Acute orchiepididymitis reveals an enlarged testis and/or epididymis with diffuse hypoecho and distinct borders. When forming an abscess, it appears as a non-homogeneous hypoecho. Hydrocele can also be seen in some patients (Fig. 14.8).

Acute orchiepididymitis should be differentiated from the tumor of the testis.

14.4.5. Tuberculosis of the testis and epididymis

14.4.5.1. *Clinic and pathology*

These are the secondary diseases of urinary tuberculosis, but most testile tuberculosis are caused directly by epididymal tuberculosis. The scrotum becomes swollen with or without a slight pain. The clinical course is slow. The epididymal nodes and/or spermatic cord nodes could be palpated in the clinic. Many nodes are localized in the tail of the epididymis.

14.4.5.2. *Sonographic Expression*

The testis or the epididymis become irregularly enlarged and a poorly-defined, non-homogeneous echo-dense node may be seen. In some cases, there may be a calcified

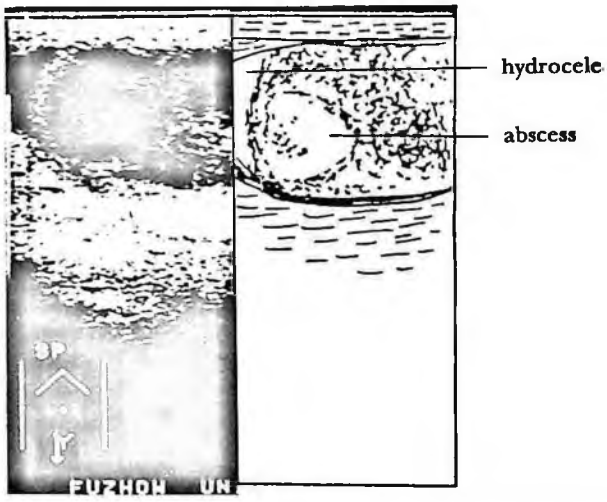

Fig. 14.8 Abscess formation in acute orchiepididymitis.

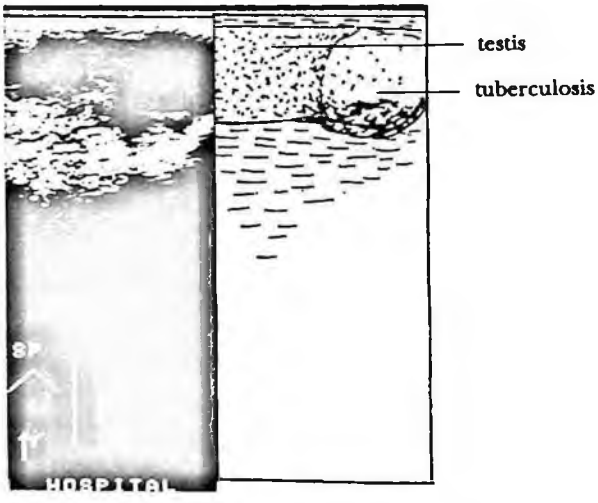

Fig. 14.9 Tubercolosis of the epididymis.

hyperecho point, or node, and a fluid area containing light spots when the abscess is formed (Fig. 14.9).

14.4.6. Other Diseases of the Scrotum

14.4.6.1. *Tumors of the Epididymis*

It is not a common disease in clinics. 80% of them are benign tumors, such as liomyoma, adenoid tumor, mesothelioma, etc. The tumors are often found in the tail of the epididymis. Many of them are unilateral. Their sonogram shows an enlarged epididymis with a well-

defined, non-homogeneous encho-dense node. Some of them appear as a recticular fluid area (Fig. 14.10).

14.4.6.2. *Spermatocele*

It is a retention cyst containing sperms in the head of the epididymis or the spermatic cord. The sonogram of the spermatocele shows a well-defined, round, sharply marginated echoless region. Its diameter is about 1–2 cm. Some are bigger than the testis (Fig. 14.11).

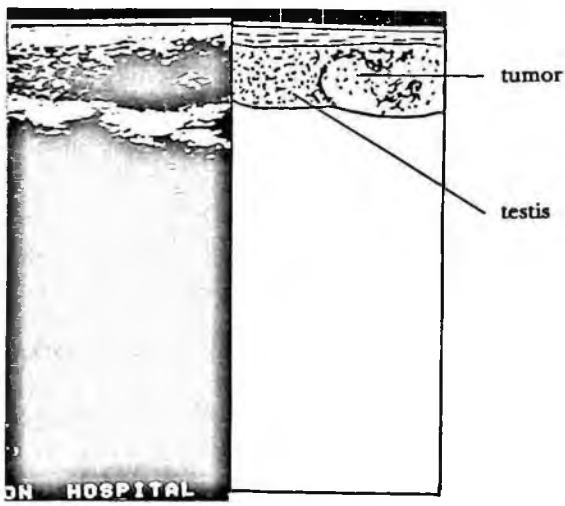

Fig. 14.10 Tumor of the epididymis.

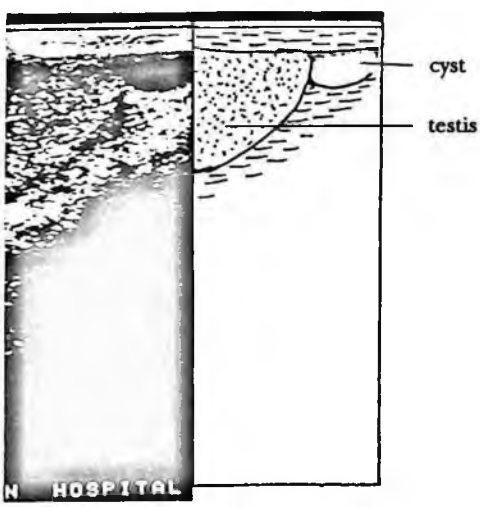

Fig. 14.11 Spermatocele.

14.4.6.3. *Scrotal Stone*

It is characterized by a sonogram with one or multiple mobilizable hyperecho masses with a sound shadow in the tunica vaginalis.

14.4.6.4. *Inguinal Hernia*

It shows a solid irregular hyperecho mass continuous with the inguinal canal, not surrounding the testis. The volume of the mass can vary with the intra-abdominal pressure.

14.5. APPLICATION OF COLOR DOPPLER FLOW IMAGE IN THE DIAGNOSIS OF DISEASES OF THE SCROTUM

14.5.1. Acute Disease

The normal testis shows less flow and the normal epididymis shows no flow on color Doppler sonograms, so the presence of increased color Doppler flow in the testis and epididymis represents inflammation. Although testicular tumors may also show hypervascularity, the presence of pain allows for distinction between inflammation and a testicular tumor. In the testicular torsion appears an absence of examinable flow in the affected testis. A paratesticular hematoma presents a mixed-echoic avascular mass with displacement of the peripheral tissues and vessels.

14.5.2. Varicocele

Color Doppler sonography can show the interial and exterial spermatic vein and the pampiniform plexus. The diameter of a normal spermatic vein is less than 2mm. The reflux of the interial spermatic veins in the absence of any palpatory sign of varicocele and the shunt of pampinifrom plexus out via the ultrasonic viable dilated exterial spermatic vein could be observed by color Doppler sonography. Based on the degree of venous reflux, these have been graded into the following four manners: Grade 0 shows no venous reflux. Grade 1a shows short venous reflux during the Valsalva manoeuvre, Grade 1b shows continuous venous reflux during the Valsalva manoeuvre, Grade 2 shows venous reflux occurring at the end of deep respiration and increasing during the Valsalva manoeuvre, Grade 3a shows short spontaneous reflux during quiet respiration, and Grade 3b shows continuous spontaneous venous reflux during quiet respiration. In Grade 3, venous reflux is increased at the end of the deep respiration and during the Valsalva manoeuvre.

Chapter 15

Ultrasonic Imaging Diagnosis of the Diseases of the Abdominal Wall and Retroperitoneum

Yang Faduan, Lin Liwu, Du Huiling

Among conditions such as enlargement, inflammation, injury, parasitic infection and abnormal positioning of the organs of the abdominal wall, peritoneum and interperitoneal space, some of them will produce symptoms clinically. These may be various degree of pain, swelling, or palpable mass. For a fairly large number of cases, it is very difficult to discover the nature and position of the lesion by clinical expression and physical signs. The abdominal wall has a fairly good sonolucent window. By using ultrasonic imaging, we may observe and diagnose diseases of the abdominal wall, peritoneum and interperitoneal space through the abdomen and waist. We can also understand its relationship with the viscera in the abdominal cavity. This indicates a specific diagnostic value.

15.1. GENERAL DESCRIPTION OF THE PATHOLOGY OF THE DISEASES OF THE RETROPERITONEAL

15.1.1. General Description of the Anatomy of the Retroperitoneal

The retroperitoneum or retroperitoneal space is the space between the parietal layer of the peritoneum and the internal fascia of the posterior abdominal wall as well as the wall of the pelvic cavity, being a portion of the abdominal-pelvic cavity.

Boundary: the anterior boundary is the posterior part of the parietal layer of the peritoneum, and the posterior boundary is the internal abdominal fascia. The upper boundary begins from the diaphragm, the lower boundary to the sacral promontory. The two lateral boundaries are the extra-peritoneal alveolar tissues connecting outwards.

Retroperitoneal organs: the descending and lower portion of the duodenum, the pancreas, kidney, suprarenal gland, ureter, urinary bladder, vagina, abdominal aorta and its branch, the inferior vena cava and its subordinate branch, the lymphatic duct, lymph nodes and nerve.

Therefore, the retroperitoneum is a big potential space filled with organs and tissues. These organs and tissues embrace the space and fill it with fat and loose connective tissues.

15.1.2. Classification of the Diseases of the Retroperitoneum

15.1.2.1. *Inflammation and Tumorous Lesions*

These include inflammation, abscess, tuberculosis, actinomycosis, idopathic retroperitoneal fibrosis, giant lymph node hyperplasia, plasma cell granuloma, and lipomatoid disease of the pelvic cavity.

15.1.2.2. *Cyst*

This includes the urogenital cyst (including the mesonephric cyst and the Muller's duct cyst), lumphohatic cyst, chylus cyst, mesocolon cyst, and enterogenous cyst.

15.1.2.3. *Tumor*

These include:

(a) Urogenital tumors: mesonophroma, malignant mixed mesodermal tumor.
(b) Genital cell tumor: benign cystic teratoma, germinoma, endodermal sinus tumor, chorioepithelioma, and malignant teratoma.
(c) Mesodermal tissue tumors: fibroma, fibrosarcoma, lipoma, liposarcoma, lieomyoma, leiomyosarcoma rhabdomyosarcoma, vascular tumor (including lymphanlieomyoma), mesodermal tumor, mesodermalsarcoma, fibrous tissue cell tumor.
(d) Neurogenic tumors: neurilemmoma, malignant neurilemmoma, neuroblasfoma, and paraganglioma.
(e) Metastatic tumors.

15.1.3. General Description of the Pathology of Common Retroperitoneal Diseases

15.1.3.1. *Hyperplasia of the Giant Lymph Node*

This is a disease with an unknown cause. It inflicts the patient with a large enlargement of benigh lymph nodes. In the majority of cases, the presence of a tumor is the main clinical symptom. Some cases are accompanied by low fever, anemia and hyperglobulinemai. Due to different understanding of the etiology of the disease, various nominations are given. They are the giant hemolymph, lymph node hamartoma, benign giant lymphoma, hyperplasia of angiolymphofollicles, and hyperplasia of the giant lymphnode.

Macroscopic observation: This disease may occur singly or in multiples. The enlarged lymph node varies in size from 2–16 cm, some lymph nodes retain the bean shape with a capsule. Sectionally, it is pinkish-gray or light brown in color, medium texture or a little bit

hard. Articles report that the lymph node resembles (sectionally) fish flesh, and it is difficult to differentiate from maglignant lymphoma macroscopically.

Microscopic examination: there are angiohyaline-type and the plasma cell type. The typical features of the former are:

(a) lymph follicle hyperplastic hypertropy;
(b) there is marked hyperplasia of the small blood vessels inside and outside the follicles, the deuctal wall undergoes hyaline degeneration, often presenting an arrangement of concentric circles, similar to that of a thymic corpuscle;
(c) the lymph cell around the follicle often presents a laminated arrangement of "onion skin", the structure of the sinus of the normal lymph node is lost.

The plasma cell type possesses some fundamental structure of the former, but the composition of the blood vessel is lesser in the normal structure of a lymph node. There is obvious infiltration of patches of plasma cells and the Ressell body can be found.

Therefore, when the abdominal mass appears clinically and it is accompanied by fever, anemia and an increase in production of serum globulin, a differential diagnosis of hyperplasia of the giant lymph node should be made.

15.1.3.2. *Retroperitoneal Cyst*

Retroperitoneal cysts refer to cystic diseases in the retroperitoneal space which originated from different tissues. About 35% occur in people below 20 years of age, the ratio of male to female patients being 2:3.

Macroscopic observation: the size of the retroperitoneal cyst varies from several centimeters to tens of centimeters. The cyst presents a single-loculate or multiple-loculate structure. The wall of the cyst is indefinite in thickness and there is fluid inside the cyst. A mesonephric cyst often contains clear or brown fluid, the Muller's duct cyst contains green or chocolate-colored fluid, the lymphatic cyst contains clear fluid, and the chylus cyst contains chylus fluid. Benign cystic teratoma is multiple-loculate or single-loculate, grease and hair is contained within. In the cyst wall, there is a bony substance or abortive teeth. The traumatic cyst contains a choacolate-colored fluid.

Microscopic observation: the nature of a retroperitoneal cyst is defined by the lining epithelium of the cystic wall. In a mesonephric cyst, the lining epithelium of the wall is cuboid or columnar epithelium, and in some parts of the area, one may find the existence of the original renal glomeruli and renal convolute tube. In a Muller's duct cyst, the inner epithelium is flat or cuboidal in shape, the lymphatic cyst occurs due to the disintegration of the lymphatic duct due to trauma, resulting in localized accumulation of lymph fluid. It is not a true cyst, there is no inner epithelium cell and no smooth muscle tissues. It is quite different from the lymphatic duct tumor. The internal wall of the enterogenous cyst is lined with intestinal mucous membrane, and the cystic wall is made up of connective tissues and smooth muscles which have become thinner. The traumatic cyst is without an inner epithelium, the cystic wall is made up of fibrous tissues and precipitation of hemosiderosis. The benign cystic teratoma is a genital cell tumor of the retroperitoneum. In the cystic wall, one may find matured tissues of three germ layers, mainly the ectoderm and mesoderm.

15.1.3.3. *Primary Retroperitoneal Tumor*

Primary retroperitoneal tumors do not include tumors of the urogenital organs, such as the kidney, ureter, adrenal gland, pancreas and intestine. Retroperitoneal tumors include tumors of the nerve, blood vessel, fat, alveolar tissue, muscle, lymphatic tissue, fibrous tissue and tumors in the remaining of the urogenital ridge in the region. Data from clinics report that, among the benign tumors of the retroperitoneum, the majority are benign terotoma and schwannoma. The malignant tumors (in order) are liposarcoma, malignant lymphoma, fibrosarcoma and leiomyoma.

Macroscopic observation: the structure of all kinds of benign and malignant tumors of the retroperitoneum is completely similar to the structure of the respective tumors in other positions. Retroperitoneal benign tumors such as lipoma and angiolieomyoma are encircled with fibrous capsules. There is a distinct boundary between fibroma and the normal tissues, but it is without a distinct capsule. A pseudo-capsule is formed due to pressure on the tissues surrounding the tumor. A minority of benign tumors such as hemangioa also show infiltrative growth. Most malignant tumors of the retroperitoneum are without capsule, and few cases of sacroma have complete or incomplete capsules. However, the majority has a pseudo-capsule.

In microscopic examinations, there are no distinct boundaries between the normal tissues and the tumors. The size and form of the retroperitoneal tumors are not identical. Except for lipoma, which presents a lobulate structure, the majority presents a round, oval or irregular nodular mass. The property of a section of the benign tumor is mostly similar to the structure of the original tissue. For example, the section of lipoma is yellow, oily and soft in texture, while fibroma is greyish white, hard in texture and even. Malignant tumors are mostly sarcoma. The majority look like the flesh of a fish — soft in texture, often accompanied by hemorrhage, necrosis, and sometimes undergo acystic degeneration area. Partial characteristic of the original tissues are still retained in small parts, for example, fibrosarcoma and some of the tissues of lieomyosarcoma possess a whirlpool structure, liposarcoma may appear yellow and the charateristics of the original tissues may be completely lost.

Macroscopic observation: retroperitoneal tumors are mostly soft–tissue tumors. A majority of benigh tumors have their histological morphology similar to that of the original tissues. But the amount of all the different tissues contained in the tumor is more than that in the normal tissues and they are irregularly arranged. The structure of the cellular morphology is identical to the cell of the original tissue. All sarcoma in the retroperitoneum are very different from the original tissues, but some vestige of the original tissue can be found in all the different types of sarcoma, for example, a striated line can be found in rhabdomyosarcoma, myogenic fibres can be found in lieomyoma, and fat cells are contained in liposarcoma. In protuberant fibrosarcoma, these may be mat-like or whirl-like in structure. In addition, all kinds of sarcoma, due to different degree of differentiation of the tumor cells, have different tumor cell morphology.

It is worth mentioning that when it is difficult to judge the benign and malignant nature of a tumor derived from soft tissues, it is usually due to:

(a) The histological morphology of certain benign tumors and tumorous hyperplastic lesions similar to that of the malignant ones. The commonly seen ones are

rhabdomyoblastoma, embryonic rhabdomyosarcoma, and myositis ossificans, are being mistaken for osteosarcoma;

(b) Certain benign and malignant tumors derived from the same tissue lack clear-cut differences, such as mesothelioma and mesothelisarcoma, lieomyoma and rhabdomyosarcoma, non-typical fibroxanthoma and fibrous tissue cell sarcoma;

(c) Certain malignant tumors derived from different tissues may have similar histological morphologies, such as multiform rhabdomyosarcoma, multiform liposarcoma and fibrous tissue cell sarcoma. They all have fantastically shaped giant and valuolated cells, with multiple forms which lead to difficultly in differentiation.

15.1.3.4. *Primary Retroperitoeal Fibrosis*

This disease is also called idiopathic retroperitoneal fibrosis. It is a lesion of hyperplasia of retroperitoneal tumorous fibrous connective tissues which appear due to unknown causes. Many people consider this disease to be a kind of allergy, or a disease of self-immunology. In addition, certain medicine may induce this disease. This disease may be related to radiotherapy and certain infections. It is mostly contracted by males. The incidence of this disease is often higher in patients of 40–60 years of age, and the course is long. The main expression in the primary stage is a dull pain in the lumbosacral, axilliary and the lower abdominal region. It is accompanied by fatigue, anorexia, and occasionally with fever. The physical examination may reveal a palpable mass in the abdomen or pelvic cavity. During the late stage of these disease, the retroperitoneal organs and tissues embraced by the fibrous tissues become oppressed, or obstructed, due to contraction of the fibrous tissues, such as oliguria, anuria, lower extremity and hydrocele of the scrotum and thrombophlibitis.

Macroscopic observation: the retroperitoneal has no capsule, there is a white fibrous mass with an unclear boundary, the sizes are different and the shapes are irregular.

Microscopic examination: fat tissues from the early stage undergoes degenerative necrosis, followed by dissolution and loss of fat. There are all kinds of cellular infiltration in the mesoderm, and there are giant cells in the late stage. A large amount of dense collagen fibers is accompanied by hyalinization and calcification. Angitis may often appear.

15.2. METHOD OF EXAMINATION

15.2.1. Condition of the Apparatus

Realtime ultrasonic imaging apparatus is chosen. Use a linear array or convex mode probe. A frequency of 3–3.5 MHz is normally used, but for children a 5 MHz-probe is used.

15.2.2. Preparation Done by the Patient

Since it is often necessary to differentiate diseases of the abdominal wall and peritoneum from diseases in the abdominal cavity and retroperitoneum, in order to decrease interference of gas in the gastrointestinal tract, fasting, cleaning the enema and drinking of water to fill

the stomach and intestine (or keeping the bladder filled prior to the examination) are often required when preparing the patient.

15.2.3. Method of Examination and Diagnosis

15.2.3.1. *Method of Examination*

(a) In accordance with the position of the lesion, the respective phsyical positions may be applied to fully expose the area of examination.
(b) In accordance with the data clinically provided for focal examination, understand the relationship between the lesion and the surrounding viscera.
(c) In accordance with the anatomical divisions, undergo examination by order.
(d) When examining the lower abdomen, one should pay special attention to the examination of the iliac fossa. The external iliac artery and vein may be taken as the anatomical landmark to observe the condition of the lesion surrounding the blood vessel. For instance, deformity of the iliac blood vessel due to oppression mostly indicates the result of oppression by retroperitoneal mass.
(e) We applied pressure to observe the condition of the local variation, to differentiate between the genuine and false mass, and the nature of the mass.
(f) Bilateral comparative observation. During the examination of symmetrical positions such as the lumbar region and iliac fossa, bilateral examination is often applied for comparative observation to ascertain the existence of a lesion or mass.
(g) To determine the position of the lesion, one may change the physical positions, or ask the patient to do deep respiration. Alternatively, the examiner may use another hand to push and press in order to observe the relationship between the lesion, or tumor, with the nearby viscera.

15.2.3.2. *Method of Diagnostic Analysis*

(a) To determine the nature of lesions such as cystic, parenchymal, benign or malignant lesions, we can depend on the observations of the size, amount, motility, outline and internal echoes of the lesion or tumor mass.
(b) In accordance with the location of the mass and the relationship with the viscera, the origin of the lesion or mass is determined. If there is a definite distance or separation by gas between the mass and viscera, it indicates that there is no distinct relationship between the mass and viscera. If the tumor mass is close to the big blood vessel of the abdominal wall or to both sides of this vertebral column, it mostly indicates a retroperitoneal mass.
(c) Familiarizing oneself with the abdominal anatomy and common diseases of each region is useful for ascertaining the origin of the lesion or mass.
(d) The retroperitoneal mass may have the following characteristics:

    (i) During examination from the abdominal wall, the gas in the intestinal tract is always in front of, or on two sides, of the tumor mass. There is absolutely no gas echoes at its posterior;
    (ii) A sign of separation between the liver–kidney border or spleen-kidney border. Under normal conditions, the liver is in close contact with the right kidney, or the

spleen is in close contact with left kidney, and thus are found in the retroperitoneal mass located posterior to the liver or spleen. The kidney will be displayed downwards, or forward, along with its continuous growth, the mass intervenes between the liver and the right kidney, or the spleen with the left kidney, resulting in the separation of the liver-kidney or spleen-kidney.

(iii) A sign of displacement of the blood vessel on the posterior abdominal wall. The tumor which is located between the abdominal aorta and inferior vena cava may cause the distance between these blood vessels to increase. The tumor located at the lateral side of the abdominal aorta or inferior vena cava may reduce the distance between these two blood vessels. In the sonogram, the mass embracing the inferior vena cava may show signs of the inferior vena cava penetrating through it. The tumor located in front of the vertebral column and posterior to the abdominal aorta and inferior vena cava raise up these two blood vessels, presenting a tubular-like or arch-bridge-like form. These signs of displacement of the blood vessel are an important basis for the diagnosis of the retroperitoneal mass.

(iv) A sign of distancing from the vertebral column. When there is a tumor mass existing between the organs closely in contact with the vertebral column, such as the two kidneys, ureter, pancreas and big blood vessel, one will often see a forward displacement of the above-mentioned organs, resulting in the organ distancing itself from the vertebral column.

(v) Gas "crossing hump sign". When a retroperitoneal mass protrudes into the abdominal cavity, the gas in the intestinal tract, which is in front of the tumor mass will follow the *to-and-fro* movement of respiration to cross the tumor mass, forming the gas "crossing hump sign".

(vi) A sign of rarely seen ascitic fluid. A malignant tumor growing in the abdominal cavity normally show signs of ascites at the late stage. Even if the volume of the tumor in the retroperitoneum is large, its growth is rapid, but it is seldom accompanied by ascites. Therefore, a sign of ascites may be considered as a contradiction of a retroperitoneal tumor.

15.3. SONOGRAM OF A NORMAL ABDOMINAL WALL AND PERITONEUM

A well modulated sonogram of the abdominal wall presents many layers of linear strip-like images. Starting from the superficial to deep layers are the skin, subcutaneous fat, fascia, muscle, extra fatty layer, and the innermost layer is the parietal layer of the peritoneum. The outermost layer of the skin, the epithelial, has bright and clear echoes, the echoes of the subcutaneous fat layer is low and dark. Its thickness varies with the individual. Echoes of the fascia and muscles are stronger than those of the fatty layer. The thickness of the anteperitoneal fatty layer also varies greatly, presenting a marked low-level echo dark area. Its inferior is delicate, bright and fine linear echoes of the parietal layer of the peritonum is parallel to it. It moves with the internal organs during respiration, while the linear strip echo of the parietal layer of the peritoneaum is fixed and without change (Fig. 15.1).

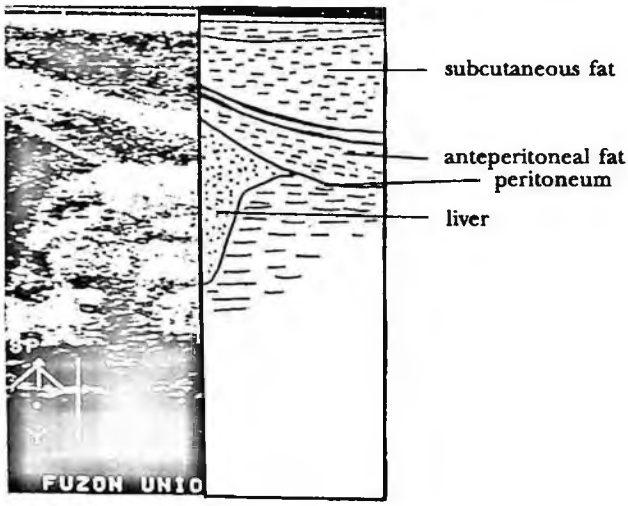

Fig. 15.1 Sonogram of the layers of the abdominal wall.

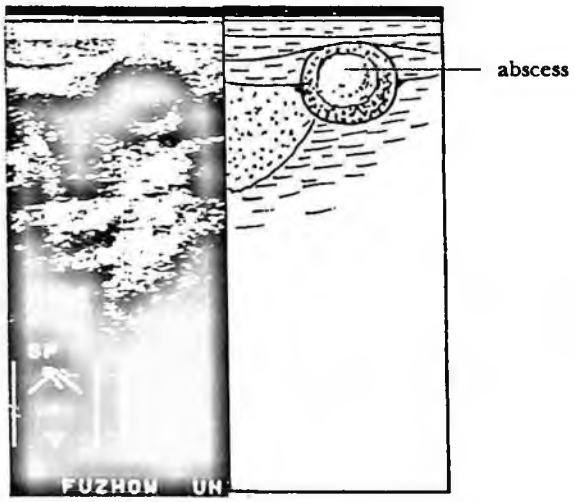

Fig. 15.2 Abscess of the abdominal wall.

15.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE ABDOMINAL WALL AND RETROPERITONEUM

15.4.1. Inflammation of the Abdominal Wall

Diagnosis of superficial inflammation is easily defined. Inflammation of the deep portion of the abdominal wall muscles, such as cellulitis of the space outside the peritoneum, particularly that located at the right upper abdomen, is often misdiagnosed as hepato-biliary system disease.

Sonographic expression:

(a) The inflammatory enveloped mass is located at the deep portion of the abdominal wall, outside the peritoneum;
(b) The internal echo is uneven, the boundary is blurred and unclear;
(c) Different forms of the echoless dark area appear after the formation of an abscess;
(d) Patients with a localized abscess may have thickened circular strong echoes (Fig. 15.2)

15.4.2. Lipoma of the Abdominal Wall

The benign tumor often located subcutaneously to the abdominal wall presents a flattened-round or lobulate shape with a thin fibrous capsule. It takes various forms, and grows very slowly. Palpation is not clear in a fat person.

Sonographic expression:

(a) Low-level echo of the substantial dark area;
(b) The boundary is clear, fine echo of capsule may be found;
(c) It cannot be easily differentiated from liposarcoma by the sonogram.

15.4.3. Fibroma and Fibrosarcoma

These are often seen in the sheath of the rectus abdominis or muscular tendon. The texture is very hard. Fibrosarcoma is usually deep-seated, and its volume is often larger than that of a fibroma.

Sonographic expression:

(a) At the muscular sheath or muscular tendon, a substantial mass with even echoes may be found;
(b) The boundary is clear, the echo of fibrosarcoma is low-level;
(c) The tumor grows rapidly in the following observations.

15.4.4. Hernia of the Abdominal Wall

Abdominal viscera or tissues make their way out through a congenital or acquired cleft in the abdominal wall, resulting in hernia of the abdominal wall.

Sonographic expression:

(a) The image varies with different contents. In the omentum major, an uneven substantial echo is found. If the intestine contains gas, a striking variation of the gas echo will be displayed, intestinal peristalsis may even be found. If it is vesicocele, a fluid dark area will be displayed.
(b) The mass of the abdominal hernia will expand or constrict with changes in abdominal pressure. Sometimes, the contents of a sliding hernia may slide in and out of the hernia orifice.

15.4.5. Peritoneal Tumor and Metastatized Carcinoma

The sonogram may show a thickening of the peritoneum, and adhesion or formation of irregular low-level echo mass, or nodular variation. The clear, light strip line of the parietal and visceral layers of the peritoneum is lost. Both are blurred and present irregular thickening. There are ascites in the abdominal cavity. Sometimes in the echoless dark area of ascites, one may find floating light dots (Figs. 15.3 and 15.4).

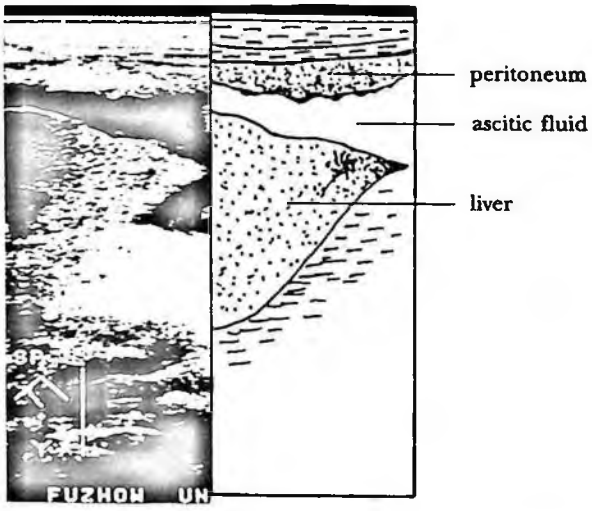

Fig. 15.3 Metastatic carcinoma to the peritoneum causing irregular thickening of the peritoneum.

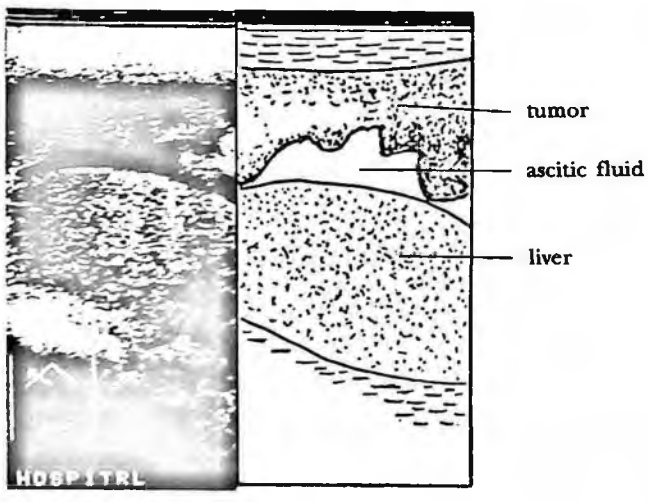

Fig. 15.4 Mesothelioma of the peritoneum extending from the surface of the liver to the diaphragm.

15.4.6. Tuberculous Peritonitis

This disease is often secondary to tuberculosis of the other organs. There are three pathological types:

(a) Exudative type — various degree of serous fibroglobulin exudative fluid accumulate in the abdominal cavity, there are minute tuberculous nodules scattered on the peritoneum, followed by the development of a lesion. Small nodules may fuse together to form a big nodule or mass, this type is more commonly seen;
(b) Adhesive type — there is precipitation of large amounts of fibroglobulin, causing a distinct thickening of the peritoneum and omentum. It adheres extensively to the intestinal tract or mesentery forming an irregular mass. This type is more commonly seen;
(c) Caseous type — seldom seen, mainly with a caseous necrotic lesion. The intestinal tract inside the abdominal cavity adheres together, forming tuberculous granular tissues or caseous material.

Sonographic expression: the sonogram varies with different pathological types.

(a) The exudative type presents a single or many echoless dark areas, the margin is clear. One may find unevenly distributed light dots and large amounts of exudative fluid forming ascites in the dark area.
(b) The adhesive type may present an irregular enveloped mass containing gas, without a clear boundary.
(c) The caseous type may have localized irregular echoes and uneven hyperechogenic masses.

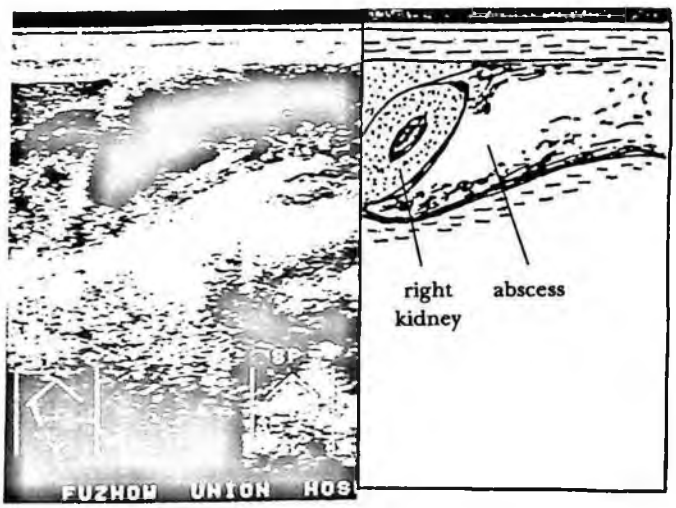

Fig. 15.5 Abscess at the lateral groove of the right colon up to the hepatorenal fossa and down to the pelvic cavity.

15.4.7. Retroperitonel Cyst

The main ones are benign cystic teratoma (dermoid cyst), cystic lymphoma, and congenital cyst.

Sonographic expression:

(a) Single-loculated or multiple-loculated echoless dark area. Sometimes, one may find a nodular hyperechogenic mass by the cystic wall protruding into the cavity;
(b) In teratoma, one may find a hyperechogenic mass in the dark area or light spots formed by hair. Sometimes, one may find lipoid fragments in an echoless dark area.

15.4.8. Retroperitoneal Abscess

The iliac fossa abscess is mainly located in the space between the iliac, lumbar fascia and posterior peritoneum. The sonogram displays an echoless dark area in the inguinal region, without a definite form. Sometimes, this dark area may extend to the lumbodorsal region, or downwards to the inner side of the thigh (Fig. 15.5).

15.4.9. Retroperitoneal Substantial Tumors

They are mainly lieomyoma, lipoma, fibosarcoma, neurofibroma, and hemangioma. The common features of the sonograms are:

(a) A substantial mass appears in front of the posterior abdominal wall, and its internal echo varies with different pathology of the tumor.

Lieomyoma has a rather complete tumor body, often with a lobulated nodule. The sonogram displays an irregular outline, the sonolucence of tumor tissues is fairly good, echoes are rather weak, and internally there are minute, even light dots. When the

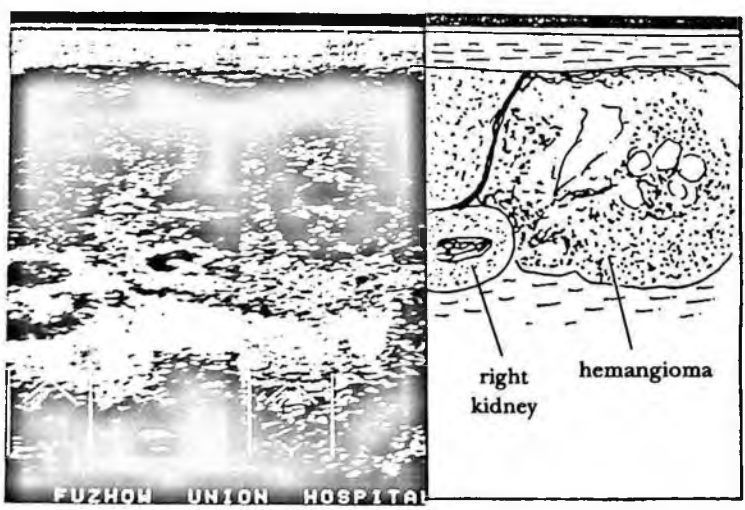

Fig. 15.6 Retroperitoneal giant hemangioma.

volume of the tumor is big, a necrotic hemorragic dark area may appear. Sometimes one may find strong echo light dots or light spots due to the calcified focus of the body of the tumor. Lipoma may often be seen beside the kidney or vertebral column, all with capsules. Its echo is lower than that of fibroma, presenting a low-level echo substantial dark area. Fibrosarcoma has a clear outline with a fibrous capsule. The sonogram shows mostly low-level echo dark areas, fine light dots, which are evenly distributed, and also a necrotic liquified dark area. Neurofibroma has a clear boundary, rather strong echoes and may have a whirl-like distribution of light dots. Hemangioma, like the abdominal aortic aneurysm, may display a pulsating dark area. Capillary hemangioma have weak echoes which are mass-like and uneven (Fig. 15.6);

(b) Non-gaseous echo at the back and in front of the tumor, and on both sides gaseous echoes may be found;

(c) The tumor mass may be separated from the liver, gallbaldder, pancreas, spleen and kidney (Fig. 15.7);

(d) The tumor mass is in close contact with the big blood vessel of the posterior abdominal wall. One often finds the abdominal aorta and inferior vena cava and their main branch oppressed or displaced (Figs. 15.8 and 15.9);

(e) No matter how big the tumor is, its posterior margin is still deep and close to the posterior abdominal wall. The margin of the benign tumor is regular, smooth and the boundray is clear. The boundary of a malignant tumor is usually irregular;

(f) The motility of the tumor with respiration is distinctively less than that of the tumor in the abdominal cavity, and the "cross hump sign" may appear. When the patient takes in deep breaths, the viscera of the abdominal cavity has a rather distinct motility with respiration, and crosses over the retroperitoneal tumor.

15.4.10. Enlargement of the Retroperitoneal Lymph Node

The commonly seen enlargements of the retroperitoneal lymph node are the metastatic enlargement of the lymph node from all kinds of carcinoma, lymphosarcoma, and the

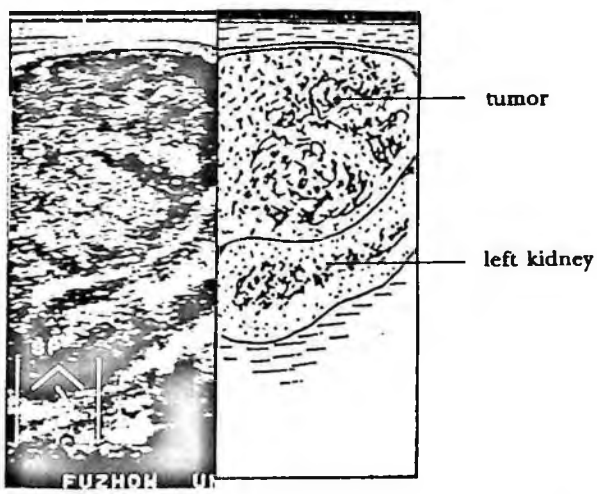

Fig. 15.7 Peritoneal fibrosarcoma oppresses the left kidney.

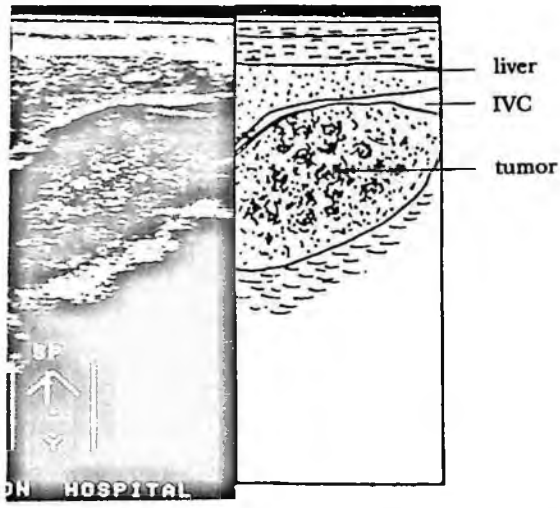

Fig. 15.8 Retroperitoneal tumor oppresses the inferior vena cava.

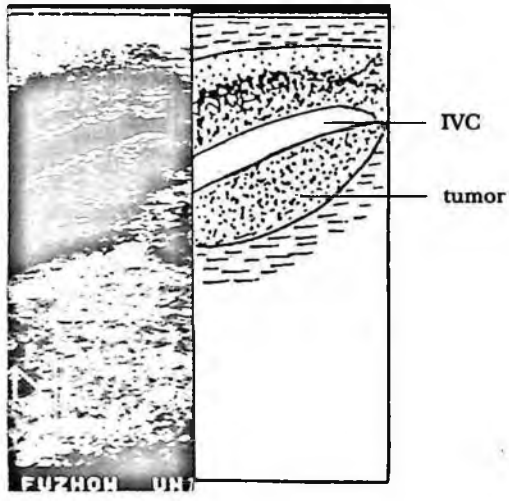

Fig. 15.9 Retroperitoneal tumor encircling the inferior vena cava.

enlargement of the tuberculous lymph node. These are often distributed on the side of the abdominal aorta or in the hilus of the kidney.

Sonographic expression: there is solitary enlargement of the lymph node, mostly presenting oval shape nodular changes. The boundary is clear, the internal echoes are often low-level. If many enlarged lymph nodes accumulate, one will find a pile distribution along the vertebral column or near the big blood vessel at the posterior abdominal wall. The morphology appears oval or round. If this is complicated with enlargement of the lymph nodes, an irregular lobulated mass will be found, which is an accumulative fusion of enalrged lymph nodes growing into one big piece. At this point of time, the internal echo is much lower, even similar to that of the echoless dark area. Sometimes, it may be mistaken for a cyst.

But the enlargement of the lymph node is mostly multiple, and the morphology is often oval. The enlargement of the retroperitoneal lymph node is often accompanied by signs of oppression, causing deformity and displacement of the big blood vessel at the posterior abdominal wall or oppression of the pancreas. Enlargement of the lymph node at the head of the pancreas will cause oppression and dilatation of the commom bile duct (Figs. 15.10–15.12).

15.4.11. Diseases of the Big Blood Vessels at the Posterior Abdominal Wall

15.4.11.1. *Clinical Value of Ultrasonic Imaging of the Big Blood Vessels at the Posterior Abdominal Wall*

Contemporary ultrasonic imaging can clearly display blood vessels at the posterior abdominal wall such as the abdoiminal aorta, inferior vena cava, portal vein and their main branches. Sonograms of all the abdominal sections can accurately display the position, size and morphology of the big blood vessels at the posterior abdominal wall, as well as the variation

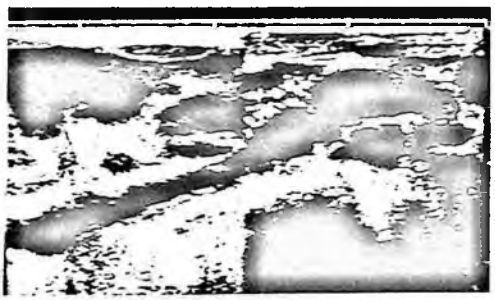

Fig. 15.10 Lymph node enlargement along the side of the abdominal aorta.

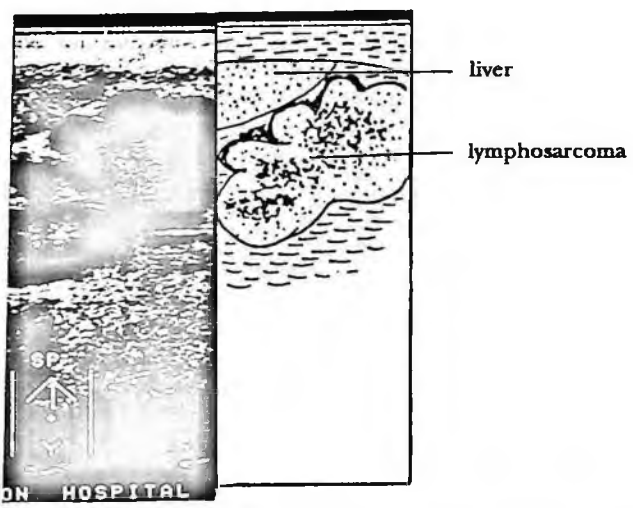

Fig. 15.11 Lymphosarcoma, fusing enlargement of the retroperitonal lymph nodes.

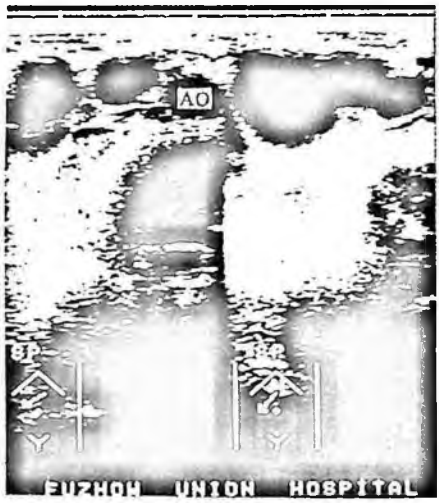

Fig. 15.12 Oppression on the abdominal aorta by enlargement of the retroperitoneal lymph node.

of stenosis, and expansion and twising under pathological conditions. At present, contemporary ultrasonic imaging is extensively used for diagnosis of self-pathological changes of the big blood vessels at the posterior abdominal wall, such as aneurysm of the abdominal aorta, embolism of the abdominal aorta and its main branch, protal vein dilatation, obstruction of the inferior vena cava, tumor embolus, and thromboembolism. Through systematic observation of the portal vein valuable data will be provided on the diagnosis and treatment of liver diseases. Of particular importance is making use of the display of the blood vessels surrounding the pancreas to serve as the base for localization of the pancreas, and in accordance with the conditions of variation, to provide effective diagnostic information to ascertain the lesion of the pancreas, such as the existence of tumor and the degree of pathological changes.

15.4.11.2. *Aneurysm of the Abdominal Aorta*

(a) Clinic and Pathology

Aneurysm of the abdominal aorta usually develops after middle age, often with the discovery of a pulsating mass in the deeper layer of the middle upper abdomen. The causes of aneurysm of the abdominal aorta are atherosclerosis, syphilitic arteritis of the abdominal aorta, all kinds of arteritis or traumatic, and congenital defects such as the Marfan Disease. They cause the destruction of the middle layer of the artery, resulting in dilatation of the local tubular wall at the abdominal aorta below the renal artery. The position of development is usually at the anterior wall or anterior lateral wall of the artery. The diameter on the larger scale may reach around 10 cm.

(b) Sonographic expression

At the longitudinal section of the median abdominal aorta at the anterior abdomen, one may find the abdominal aorta presenting localized expansion or a shuttle shape, communicating with the superior and inferior side of the normal abdominal aorta at the

end of both sides of cystic expansion (Fig. 15.13). On the cross-sectional image, a markedly dilated round or oval echoless dark area of the aneurysm of the abdominal aorta can be found (Fig. 15.14). When conducting an ultrasonic examination on the aneurysm of the abdominal aorta, besides noticing its size and dimensions, one should also notice its beginning and ending positions, particularly the relationship between its position with that of the renal artery. Finally, observe if there is complication with embolism. If there are emboli, low-level echo light dots or a light spot of organized emboli with the echoless tumor body dark area can be found.

When an aneurysm of the abdominal aorta ruptures, an echoless dark area may be found at the side of the abdominal arota, and the form may be irregular. Examining from all sections, one will find a dark area in communication with the abdominal aorta.

When the main branch of the abdominal aorta develops aneurysm, its sonogram is similar to that of an aneurysm of the abdominal aorta and at the same time diagnosis is done by observing its pulsation. But it should be differentiated from cystic disease. The author has once mistaken a case of giant aneurysm of the splenic artery for the cyst of the tail of the pancreas. Therefore, if necessary, Doppler ultrasonic examination should be done as it is useful for differentiation.

15.4.11.3. *Dilatation of the Inferior Vena Cava and Its Subordinate Branch*

The common cause of the dilation of the inferior vena cava are heart disease or disease of the inferior vena cava itself, causing stenosis obstruction of the tubular lumen, resulting in dilatation at the distal end. Examples such as pericardinal effusion, congestive heart failure, and dilated-type myositis cause the blood to flow back to the heart, resulting in dilatation of the inferior vena cava and its subordinate branch. The sonogram shows marked dilatation of the inferior vena cava and hepatic vein, the liver enlarges and the echo is homogeneous (Fig. 15.15). If the course is protracted, it may induce fibrosis of the liver, then the internal echo of the liver becomes enhanced and non-homogeneous. The Union Hospital, affiliated

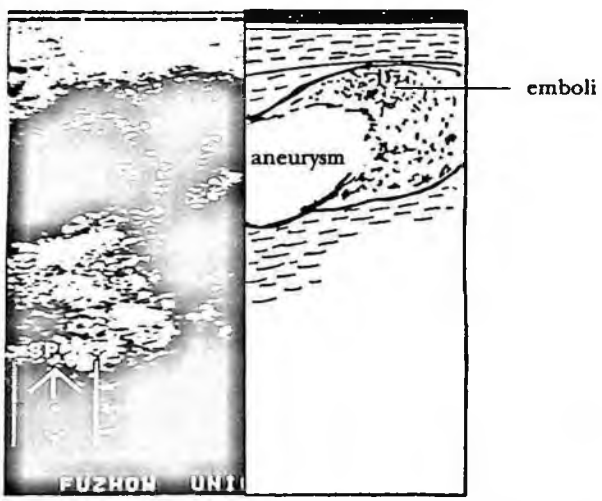

Fig. 15.13 Aneurysm of the abdominal aorta complicated with embolism (longitudinal section).

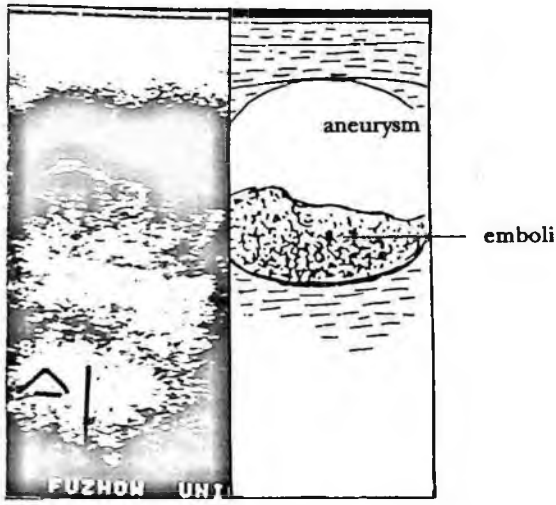

Fig. 15.14 Aneurysm of the abdominal aorta complicated with embolism (cross section).

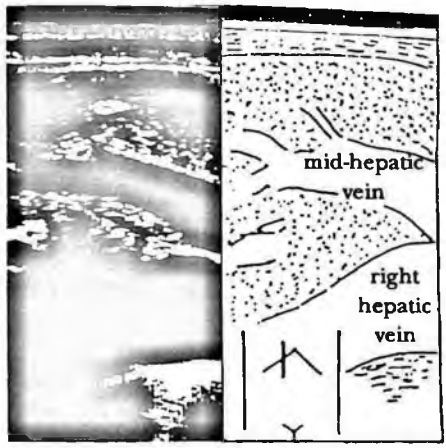

Fig. 15.15 Marked dilatation of the hepatic vein.

to the Fujian Medical University, found two cases of congenital obstruction of the inferior vena cava whose clinical expressions are the enlargement of the liver (with a hard quality) and there is marked torturous dilatation of the vein at the abdominal wall. This is clinically diagnosed (suggestively) as cirrhosis of the liver. The sonogram reveals dilatation of the inferior vena cava and hepatic vein. 3–4 cm from the cardiac end of the inferior vena cava, a substantial membranous structure with median echoes protrudes into the lumen. The upper segment (cardiac end) is markedly constricted and the right astrium is not filled, while the lower segment is markedly dilatated. The intensity of the intra-hepatic echo is uneven, which is similar to the changes encountered in cirrhosis of the liver. One of these two cases confirmed what is found in ultrasound by surgery — congential obstruction of the inferior vena cava.

Tumors which metastasize to the inferior vena cava or hepatic vein are seldom seen. They are mostly due to metastasis of maglignant tumors of the liver or kidney. Various sizes and unequal echoes of an entity may be found in the inferior vena cava or hepatic vein. The velocity of blood flow at the posterior side of obstruction is slow, and one may find moving images of piled red blood cells (Fig. 15.16). The emboli inside the inferior vena cava may present an irregular entity, closely adhered to the wall of the vein (Fig. 15.17). But it is difficult to differentiate from a tumor emboli, hence, other clinical data should be considered before diagnosis.

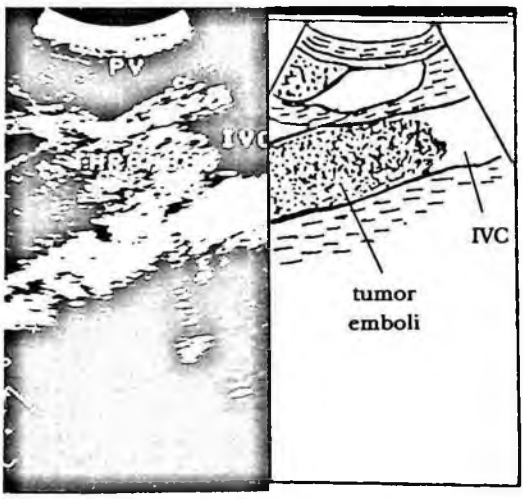

Fig. 15.16 Tumor emboli inside the inferior vena cava.

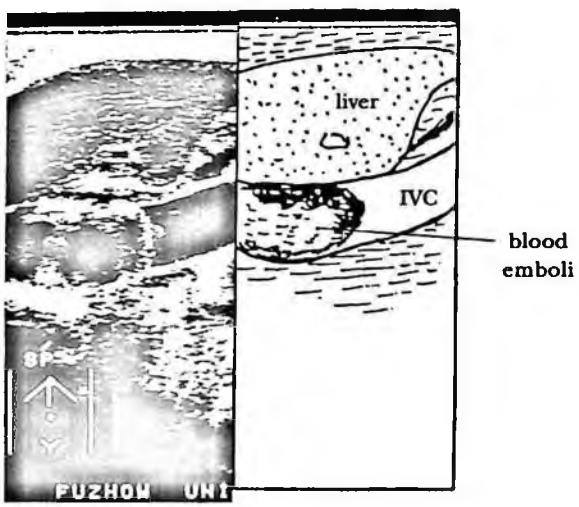

Fig. 15.17 Blood emboli inside the inferior vena cava.

Part 3

Contemporary Ultrasonic Diagnosis in Gynecology and Obstetrics

Chapter 16

Ultrasonic Imaging Diagnosis in Obstetrics

Ye Zhen, Lin Liwu

B-mode ultrasound examination can be used to directly observe the growth, development and movement of the fetus and its attachments, as well as discover and diagnose normal and pathological pregnancies. It can be used for the examination, measurement and analysis to determine the conditions of the development, weight gain and maturity of the fetus. Discovering high-risk pregnancies in time is helpful in deciding treatment so as to lower the mortality rate of both mother and infant during the prenatal period. B-mode ultrasound examination has no ill-effects on mother and infant. It can be easily manipulated without increasing the discomfort of a pregnant woman. Nowadays, it has replaced x-ray radiological examination, which has ill-effects on both mother and fetus. It is the choice method for prenatal examinations to judge the growth and development of the fetus inside the uterus.

16.1. PHYSIOLOGY OF PREGNANCY RELATED TO ULTRASOUND

The egg cell, fertilized in the ampullar portion of the uterine duct, becomes a fertilized egg which undergoes successive divisions. It takes 3–4 days to travel through the oviduct and forms a morula when it reaches the uterine cavity. The morula continues to divide in the uterine cavity to form a blastosphere. The blastosphere is implanted 6–8 days after fertilization. The place of implantation is mostly at the superior part of the posterior wall of the uterus, near the median line. Before implantation, it can be difficult to display the fertilized egg by ultrasound.

After implantation, the fertilized egg proceeds to the embryonic stage. Two weeks after fertilization it becomes a diblastula. At this stage, the amniotic sac, yolk sac and embryonic disc are suspended in the fluid of the blastocele, which can be displayed by ultrasound apparatus. Three weeks after fertilization, the embyro develops into a triderm. These three layers of the embryo form the primodium of development of the fetal body. The primitive cardiac tube and primitive gut are formed at the end of the third week. At the end of the fourth week, the yolk constricts and the umbilical cord elongates. Blood circulation within

the fetal body is established preliminarily. At the end of the 8th week, the embryo begins to take on a human form, with rapid development seen in the liver, heart and digestive tract. In the first 8 weeks, the embryo is called an embryo and after the 8th week is called a fetus. At the end of the 12th week, the genitalia of the fetus has formed, but the sex cannot be determined yet. The extremities can move, the fetal head is especially big and eyelids are closed. At the end of 16 weeks, the muscles develop, fetal motion is marked and the movement of respiratory muscles begin. At the end of the 20th week, the fetus may display the swallowing reflex. At the end of the 24th week, all the viscera have been developed. At the end of the 28th week, the eyelids open and subcutaneous fat is little. At the end of the 32nd week, the subcutaneous fat gradually increases and the testicles descend into the scrotum. At the end of the 36th week, there is some deposition of fat. At the end of the 40th week, the fetal body is well developed, the extremities become round, the hair grows about 2–3 cm and hair is dropped, the length of fetus is about 50 cm, and the body weight is about 3000 g or more. The rate of length increase in the fetus is rather constant. In the first 20 weeks of pregnancy, the length of the fetus (cm) is equal to the square of the month of pregnancy; in the last 20 weeks of pregnancy, the length of the fetus (cm) is equal to the month of the pregnancy multiplied by 5.

16.2. METHOD OF EXAMINATION

16.2.1. Apparatus

The B-mode ultrasound apparatus is used. The frequency of the probe is 2.25–5 MHz, but usually 3.5 MHz is used.

16.2.2. Precautions

(a) Most pregnant women are made to assume the supine position. Women in the late stage of the pregnancy may lie a bit on the side (mostly the left side) in order to avoid development of hypotension syndrome.
(b) B-mode ultrasound examination in the early and late stages of pregnancy require the urinary bladder to be moderately filled. In the mid stage of pregnancy, an empty urinary bladder is required.
(c) Gel is rubbed on the skin of the abdomen to ensure close contact between the probe and the abdominal wall, which is beneficial for the transmission of ultrasound.
(d) The examination procedure is such that a longitudinal section is done first. In order to get a total view of the uterus and pregnancy product, this is followed by a segmental transverse section to understand the details of the structure of the uterus, placenta and amnion. The examination should be done from top to bottom, and from left to right in order to avoid both mis-diagnosis and missed diagnosis.

16.2.3. Observation of the Pregnant Uterus by Ultrasound

16.2.3.1. *General Observations*

(a) The pregnant uterus

After pregnancy, the pregnant uterus gradually enlarges. In the 5–8th week of pregnancy, the uterus is enlarged like a ball. After three months of pregnancy, the fundus of the uterus is out of the pelvic cavity. At the end of the 4th month, it reaches between the umbilicus and the pubis. At the end of the 5th month, it reaches one finger-breadth below the umbilicus. At the end of the 6th month, it reaches one finger-breadth above the umbilicus. At the end of the 7th month, it reaches three finger-breadths above the umbilicus. At the end of the 8th month, it reaches the spot between the umbilicus and xyphoid process. At the end of the 9th month, it reaches two finger-breadths below the xyphoid. By term pregnancy the fetal head enters the pelvic floor, and the uterine fundus again descends to the area between the umbilicus and xyphoid. Due to the distance between the umbilicus and pubis of the individual, the amount of amniotic fluid, monocyesis or twin pregnancy, different conditions of fetal development, and the above heights of the fundus of the uterus is only for reference. The thickness of the wall of a non-pregnant uterus is 0.8 cm. The thickness of the wall increases in the early stage of pregnancy but decreases during the middle and late stages. Furthermore, the echoes at different positions are not alike. At the mid and late stages of pregnancy, one may sometimes find a network-like structure, similar to the "sign of sowing" in the longitudinal section of the lateral wall of the uterus. This is due to the attachment of the loose margin of the placenta and should not be mis-diagnosed as a placenta tumor.

(b) The gestation sac

After the 5th week of pregnancy (the earliest 33 days), one may find an oval or round light circle in an enlarged uterus. A liquified dark area is found in the middle, and the wall is smooth. This is the gestation sac. Take its largest section in order to measure the external diameter of the light circle.

(c) The fetal heart

The end of the 6th week after amenorrhea, is the earliest time, that the cardiac tube flashing can be examined. A rhythmic swinging of the dot-like echoes is seen inside the gestation sac. At the mid and late stages of pregnancy, the structure of the heart becomes gradually clearer, the image of the 4 cardiac cavity and big blood vessel of the fetus can be displayed. The long axis of the fetal heart is pratically perpendicular to its trunk. First, let the probe be parallel to the fetal vertebral column or the long axis of the aorta. When image is clear, let the probe rotate 90° at the level of the fetal chest, then the image of long axial, 4-cavity heart can be seen. In the left atrium, one may find the valve of the foramen ovale to vibrate due to blood flowing from the righ atrium to the left atrium.

(d) Fetal motion

Movement of the fetal extremities in the uterus is called fetal motion. At the late stage of early pregnancy, B-mode ultrasound can be used to observe fetal motion. Examination in late pregnancies should detect fetal motion. Excessive fetal motion or no fetal motion indicate the fetus is in a bad environment inside the uterus, i.e fetal distress.

(e) Biparietal diameter of the fetal head

When the biparietal diameter is measured, the outline of the fetal head should be oval in shape. The median line in the middle presents intermittence. At the cross-section of

the fronto-occipital diameter at the thalmic level, one can find two cornua of the lateral ventricle and the third ventricle. If the fetal head is round, it indicates that the position of the scanning is too high. If the median echo is not at the center, it indicates that the position of scanning is deviated. The biparietal diameter is the external diameter of the light circle of the fetal head.

(f) Spinal column

The longitudinal section of the fetus can be displayed from the great occipital foramen to the tip of the coccyx. It is presented by two parallel light bands arranged as two regular strips of beads. Between the light band is the echoless dark area of the vertebral tube. The coccyx is raised backwards. The cross-section of the vertebral column is a closed light circle, the central attenuation is the spinal cord.

(g) Classification of the thickness and maturity of the placenta

Seven weeks after amenorrhearra, the dense echogenic dots appear outside the gestation sac which marks the beginning of the development of the placenta. After 12 weeks of pregnancy, the placenta is completely formed, presenting lunar dense, minute dot–like echoes, which are evenly distributed. The fetal side of the placenta is the villus lamina, presenting a white linear echo. The materal side of the placenta (basal lamina) is concave, its margin gradually becomes thinner to mingle with the muscular wall of the uterus. In the late stage of pregnancy, the parenchymal echo of placenta has a blood sinus, echoless, small, dark area. To measure, the thickness of placenta, take the thickest part.

The classification of the maturity of the placenta is in accordance with the classified methods advocated by Crannum (1979), which is divided into 4 classes:

Class 0 — the ovillus lamina of the placenta presents a smooth, even line. The placenta is without calcified spots;

Class I — the villus lamina of the placenta enters the placental tissue, it is slightly concave, presenting a light floral border. Small, scattered echogenic dots are seen in the placental tissue;

Class II — the villus lamina of the placenta further enters the placental tissues concavely, presenting a deep arc floral border. The basal lamina can be seen but it is not joined with the villus lamina, and the echogenic dots increase in size in the placental tissues;

Class III — the basal lamina and villus lamina of the placenta join together, forming isolated, irregular light circles. These light circles represent the small lobe of the placenta (margins of the small lobe are practically calcified).

(h) Observation of the amniotic fluid

The important observation points of the amniotic fluid includes the clarity of the aminiotic fluid and the width of the dark area. In general, the dark area of the aminotic fluid is sonolucent. Small amounts of minute echogenic dots are normal. But large amounts of echogenic dots are found in the amniotic dark area, or too many echogenic dots found in the dark area during oligoamnios are due to the amniotic fluid being contaminated with meconium and becoming turbid. The width of the amniotic fluid refers to the anteroposterior diameter of the widest part of the amniotic dark area. If the amniotic fluid is cut into several segments by the extremities of the fetus, it should progressively accumulate the calculated values.

Ultrasonic measurement of the amount of amniotic fluid still has no unified standards. It is considered, in general, that the normal maximum diameter of the amniotic dark area should not be over 9 cm and the minimum value not less than 3 cm. Hollamder points out that after 32 weeks of pregnancy, if a space the size of two equal fetal heads is displayed inside the amniotic cavity of single gestation, hydramnios can be diagnosed immediately. When measuring the width of the amniotic fluid, the probe is placed perpendicular to the anterior abdominal wall.

(i) Umbilicus

Its sonogram shows a chord-like echo. The longitudinal section displays the umbilical vein and umbilical artery, the dark area of the tubular lumen and the tubular wall are parallel at the light band echo. The short axial section may show one big and two small echoless dark areas inside a round circle. During the observation, one should notice whether the cross-sectional echo of the umbilicus is found in the longitudinal section of the neck region. If an echo of the umbilicus is found, it is diagnosed as the umbilical cord around the neck.

(j) Identification of the fetal position

The relationship between the indicating point of presentation of the fetus with the materal bony pelvis is called the position of fetus (fetal position in short). The indicating points for occipital presentation is the occipitale, the facial presentation is the maniduble, the breech presentation is the coccyx, and the shoulder presentation is the scapula. According to the relationship between the indicating points and the left, right, anterior, posterior and transverse sections of the maternal pelvis, there are different positions of the fetus.

During the ultrasound examination of the fetal position, in the vertex presentation, one looks for the great occipital foramen at the beginning of the vertebral column and in the breech presentation, one looks for the coccyx. The different positions of the fetus are determined by the relationship between the great occipital foramen and the occyx, and the left, right, anterior, posterior, and transverse position of the maternal bony pelvis. When the exact occipital posterior is at the transverse section of the median abdomen above the pubic bone, the two eye sockets and one nasal fossa can be found at the same time.

16.2.3.2. *Observation of Fetal Growth and Development*

Besides the general items observed mentioned above, the following structures should also be observed:

(a) Crown-rump length of fetus:

8 weeks after pregnancy, the outline of the fetal body can be clearly seen. Move the direction of the probe to find measure the maximum distance between the top of the fetal head and fetal buttock.

(b) Frontoccipital diameter

When the fetal back is near the lateral wall of the uterus, do a longitudinal section according to the position of the fetal vertebral column. The ultrasonic tomograph image of the fetal head, occipital prominence and the root of nose can then be identified.

The distance between the lateral border of the light circle of the occipital prominence and the lateral border of the light circle of the nasal root will be the OFD.

(c) Head circumference (HC)
Measure the transverse diameter and anteroposterior diameter of the OFD at the thalmic evel. The HC can be obtained from these measurements. Nowadays, many apparatus use an electronic ruler to measure the HC directly.

(d) Abdominal transverse diameter (ATD) and abdominal circumference (AC)
Take a cross-section perpendicular to the vertebral column. One will be able to find the liver tissues encircling the umbilical vein canal, vertebral column, stomachic bubble, and abdominal aorta. Measure its transverse diameter and anteroposterior diameter. Measure the AC with an electronic ruler.

(e) Thoracic transverse diameter (TTD) and thoracic circumference (TC)
Take a maximum cross-section of the thoracic cavity perpendicular to the vertebral column at the place where the motion of the 4-cavity heart and mitral valve is most marked. Measure the diameter of the outer border of the light circle at this cross-section to get the transverse diameter and anteroposterior diameter. The TC is measured with an electronic ruler.

(f) Measurement of the anteroposterior diameter of the fetal liver
When scanning the upper abdomen, move the probe along the inferior of the bar-like rib echo, then the liver image may be displayed. The fetal liver presents a lunar section when a longitudinal section of the fetal liver is taken. The hilus of the liver appearing at its lower margin is used as the standard. Measure the maximum distance between the outer border of the light band of the anterior and posterior surface of the liver.

(g) Fetal kidney
The cross-section of the two kidneys present a circular structure at both sides of the vertebral column. A typical beam-like structure is seen in the longitudinal section. The renal collecting system and capsule have strong echoes, while the renal parenchyma has low-level echoes. Measure the length, width and anteroposterior diameter of the two kidneys.

(h) Length of femur (FL)
The measurement may be made on the 12–13th week of pregnancy. There are two ways of measurment:

(i) Move the probe perpendicular to the vertebral column until the sonogram reveals the femur. Then gradually turn it 30°–40° facing the abdominal walls until a sonogram of the entire length of the femur is clearly displayed, then fix the image. Repeat the measurements of length more than two times, and take the maximum length;

(ii) At the longitudinal section, move the probe along the direction of the femur until the sonogram of the femur is displayed, then gradually move it 40°–60° away from the abdominal wall until a sonogram of the entire length of the femur is displayed. Then measure the length of the femur.

(i) Ossification center of the fetal epiphysis
Strong echoes of the fetal epiphysis revealed in the ultrasonogram represents the center of the ossification of the epiphysis. One can measure the ossification of the epiphysis at the distal and proximal end of the femur. The former appears at the 36th week of pregnancy, the latter at the 38th week.

16.3. ULTRASONIC IMAGING DIAGNOSIS OF A NORMAL PREGNANCY

The gestation period is counted from the first day of one's last menstruation. Altogether, there are 40 weeks or 10 gestational months. Before the end of the 12th week is the early gastation, the 13th–27th week represents the metrimester gestation, and late gestation is after 28th weeks. Childbirth in the 38th to the end of 42nd week is called full term delivery, and 42 weeks of gestation is called a prolonged gestation.

16.3.1. Ultrasonic Diagnosis of Early Gestation

16.3.1.1. *Enlargement of the Uterus*

In the early stage, the anteroposterior diamater of the uterus is enlarged, causing the uterus to become ball-liked. At the late stage of early gestation, it is markedly enlarged. Inside the uterus, one can find echoes of the embyro and its attachment.

16.3.1.2. *Appearance of the Gestation Sac*

The earliest discovery is 30 days after amenorrhea. In the uterine body, a small light patch, about 0.5 cm in diameter, is found. Re-examination 35 days after amenorrhea shows that this light path gradually becomes a round light circle of 1 cm in diameter. Inside the light circle is an echoless area, which is the gestation sac. The diameter of the gestation sac increases as gestation progresses. It gradually disappears 11 weeks after amenorrhea. On the 13th week the gestation sac has completely disappeared. Because the amniotic cavity fills the entire uterine cavity coinciding with the uterine wall (Fig. 16.1), gestational age can be calculated by the size of the gestation sac, indicating the development of the embryo. Zhang Fengrong *et al.* worked out a formula according to 204 cases of normal measurement of the GS.

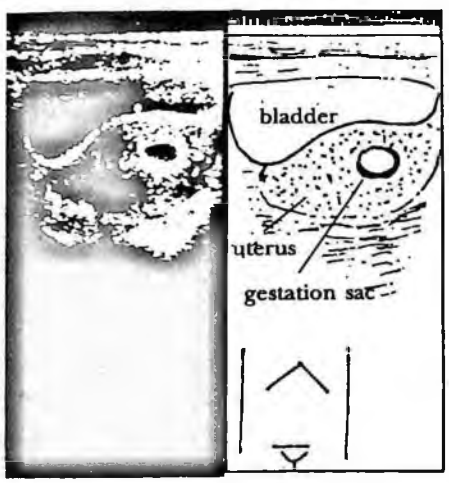

Fig. 16.1 Sonogram of early gestation.

$$YGS = 0.5512 \times \text{week of gestation} - 1.003$$
$$S = \pm 0.153$$

The rate of accuracy is 95% (Y — the largest diameter of the embryonic sac, S — standard deviation).

16.3.1.3. *Fetal Bud*

Six weeks after amenorrhae, a small dot-like, or a small, light, patch-like embryonic tissue echo appears on one side of the gestation sac. That is the fetal bud (Fig. 16.2). It is fully displayed in the 7th week. It grows rapidly, and at the end of the 8th week of gestation, a human form begins to appear, the outline of the fetal head and fetal body appears. One may then measure the CRL of the fetus. The CRL is measured during the 8–14th week of gestation. Estimation of the gestational age is most accurate during this time. The Wuerzburg University in Germany used these measurements to compare with a constant graph to calculate the gestational age. The error is only ±3 days. Using this value to calculate the gestational age in China, the error is only 0.075 weeks. Zhang Fengrong *et al.* summed up a formula in accordance with 110 values of measurement of normal gestation.

$$CRL = 0.9330 \times W - 5.674, \text{ where W is the week of gestation.}$$
$$S = \pm 0.3510$$

The rate of accuracy is 95%.

16.3.1.4. *Fetal heart*

Early cardiac tube flashing is examined earliest at the end of the 6th week of gestation. In the echoes of the fetal bud, one can find a regular up-and-down or left-to-right pendular movement. Later, it gradually develops and can be totally examined in the late stage of early gestation.

16.3.1.5. *Placenta*

At the 7th week of gestation the placenta begins to develops. At the 9th week of gestation, the sonogram shows a complete, semilunar-shaped placenta. The placenta's position can be determined (Fig. 16.3).

Diagnosis of early gestation is mainly in accordance with the appearance of the fetal sac and fetal heart. Enlargement of the uterus and the appearance of the fetal bud have great reference values only when the embyro is suspected not to have undergone any development.

16.3.2. Ultrasonic Diagnosis of the Mid and Late Stages of Gestation

At the 13th week of gestation, one may find a complete fetal image and an echo of the attachment in the uterus. Each viscera of the fetus can also be displayed.

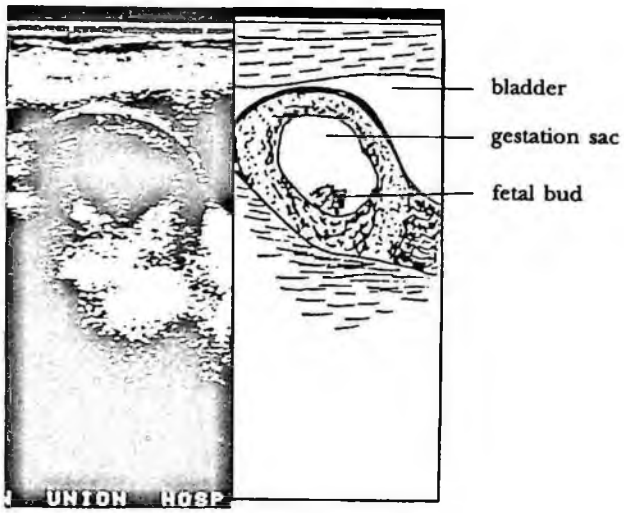

Fig. 16.2 Early gestation (the fetal bud is seen in the gestation sac).

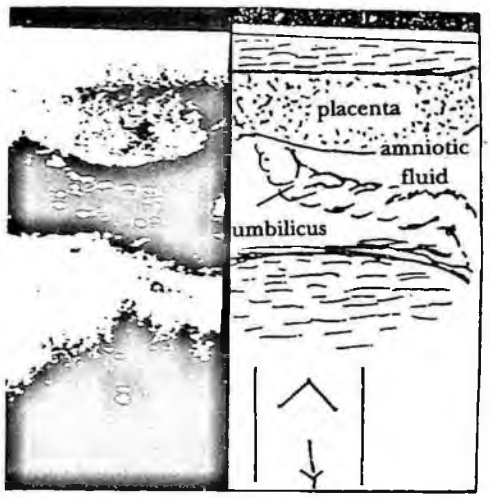

Fig. 16.3 Ultrasonograph of the umbilicus and placenta.

The items of observation revealed by ultrasound is practically during the mid and late stages of metrimester gestation similar to that of late gestation. The purpose of combining metrimester gestation with late gestation is to monitor the growth and development of the fetus, and discover deformities in the fetus early.

16.3.2.1. *Ultrasonograph of the Fetus*

After entering the metrimester gestation, one may find an image of a complete fetus. After 18 weeks of gestation, each viscera can be identified and displayed more clearly and completely along with the increase of gestational weeks.

The echo of the skeletal system is the strongest, and it is accompanied by acoustic shadows at its posterior. The cranial bone present a strong light circle. Outside the light circle, echoes of the skin and soft tissues are displayed. Sometimes, one may also find echoes of scarce hair. Inside the light circle, the mid brain line, lateral ventricle and structure of the brain tissues appear (Fig. 16.4). Through measurements of the BPD and OFD, one may calculate the gestational week of the fetus. The increase of the BPD and OFD before the 28th week of

Fig. 16.4 Sonogram of a fetal head and fetal rib.

gestation is rather stable. On the average, the increase is 3 mm per week. In the 29–36th week, the increase is average at 2.5 mm per week; in the 37–40th week, the increase is an average of 1.5 mm per week. In general, BPD in the 13th week is 2 cm, 6 cm in the 24th week and 9.5 cm in the 39th week. The vertebral column starts from the great occipital foramen, present as two rows of regular bead-like strong echoes, accompanied by acoustic shadows at its posterior. Between the two rows of light beads, there is a strip-like echoless area, which the image of the spinal cord in the vertebral tube. The upper segment of the vertebral tube is 2 mm wider than lower segment, and disappears at the tip of the coccyx. The vertebral column has a definite degree of curvature due to the curvature of the fetal body. The coccyx is raised about 15° backwards. The cross-section of the rib has round strong echoes. There are acoustic shadows below each rib which are arranged in bars. The longitudinal section of the rib presents strips and the long bones of the extremities can be displayed. The length of the long bone increases with gestational week. According to literature reports, the growth curve of the length of the femur indicate that in the 13–25th week of gestation, its growth and gestational week present a linear increase. During the 26–42nd week of gestation, the increase is rather gentle. Fingers and toes of the fetus an be identified. According to CMPNHLAKOBAH *et al.*, from 305 normal pregnant women who were in the 14–41st week, the value of FL was measured and the formula they got was:

$$\text{Week of pregnancy (W)} = 0.28\ (\text{FL})^2 + 1.59\ (\text{FL}) + 11.66$$

Inside the fetal thoracic cavity, one may find non-gaseous filling solid echoes of the lung tissues and echoes of the heart. The long axis of the fetal heart is nearly perpendicular to its trunk. At the cross-section of the fetus, one may find an image of the four-cavity heart. The right atrium is close to the anterior of the thoracic wall, with the left ventricle posterior to it. One may also find the valve of the foramen ovale at the left atrium showing the phenomenom of vibration due to blood flow from the right to left atrium. One may also observe the movement of the value. In the thoracic cavity, one may also find the thoracic aorta extending downwards to the abdominal aorta in the abdominal cavity, presenting a perfectly straight, echoless dark area.

The fetal liver in the abdominal cavity presents solid low-level echoes and the internal echogenic dots are even. In the late stage, the echo of the tubular system inside the liver can be clearly displayed. The value of the anteroposterior diameter of the fetal liver is closely related to the fetal body weight. The fetal stomach, bladder and intestine all revealed as liquified dark areas. The dimensions are periodically dilated or contracted. The fetal kidney lies on both sides of the vertebral column, which may be examined during the 15th week of pregnancy. The intrarenal structure can be displayed in the 20th week of pregnancy. The cross-section of the two kidneys presents a circular structure, the longitudinal section presents a typical structure of a bean. The renal pelvis calcix system and the capsule have strong echoes. The renal parenchyma presents low-level echoes. The renal pelvis, fully-filled with urine, is sometimes displayed clearly in cases where there is obstruction. The fetal kidney grows bigger with the advancement of the gestation week. According to literature report, in the 39th week of gestation, the length, width and thickness of the left and right kidneys may reach the following figures:

left side — 4.4 cm, 2.79 cm, and 2.31 cm
right side — 4.30 cm, 2.59 cm, and 2.37 cm.

Five months after gestation, the fetal external genitalia can be displayed. It will be displayed more clearly with the advancement of gestation.

16.3.2.2. *Fetal Breathing Movements (FBM)*

In the mid and late stages of gestation, one may find regular downward movements of the fetal diaphragm and reversible movements of the fetal thorax and abdomen — this represents the fetal breathing movements. The average frequency of breathing is 52.37 times/min. For a perinatal fetus, the lowest is 30 times/min, and the highest is 74 times/min. The mode of breathing of the perinatal fetus can be divided into regular, irregular and typical. The regular types occupy 98%. Irregular breathing (refering to the frequency difference calculated two times within 30-second interval to be more than 20 times/min) indicates fetal distress inside the uterus. In addition, literature reports abroad report that the existence of fetal breathing movements is helpful in the prediction of premature delivery. It is regarded that premature delivery patients with fetal membrane intact and those having FBM will carry on with gestation, otherwise premature labour is predicted.

16.3.2.3. *Fetal Motion*

In the middle of the late stage of gestation, the motion of the fetus can be observed. If one can find, with 10–20 minutes of continuous observation, 1 to 2 times of flexion and extension, rotatory motion of fetal trunk or extremities, then the fetal motion is normal.

16.3.2.4. *Placenta*

Placental echoes are displayed clearly. Now we may attempt to localize the placenta and classify the maturity. Class I placenta is seen in the mid and late stages of pregnancy, while class III placenta is only seen 36 weeks after gestation. In general, class I placenta's average gestational age is 31.11 weeks, with a thickness of 3.8 cm; class II placenta's average gestational age is 36.36 weeks with a thickness of 3.6 cm; class III placenta's average gestational age is 38.04 weeks with a thickness of 3.4 cm. There is an interlock between the gestational age and classification of placenta.

16.3.2.5. *Amniotic Fluid*

Observations made on the dark area of the amniotic fluid show the size of the dark area, the depth and sonolucence. Many deformed fetus result from the occurrance of polyhydramnios. The incident rate of fetal distress is high in cases with oligoamnios.

16.3.3. Ultrasonic Diagnosis of the Full Termed Pregnancy

The diagnosis of the full-termed pregnancy is mainly for determining whether the fetus is mature.

16.3.3.1. *Determination of the Gestational Age*

In high-risk pregnancies, the health of the fetus is influenced by many factors. The gestational age is the key factor determining its survival. Nowadays, through multiple parameter examination, the gestational age is predicted, with special emphasis on the soft tissues.

16.3.3.2. *Determination of the Maturity of the Fetal Lung*

The majority of the rate of morbidity and mortality of a new born is due to the immaturity of the lungs, leading to difficulty in breathing. In fact, the maturity of a fetus is estimated by the maturity of his pulmonary function. It has been proven clinically, that when the lecithin/sphingomyl glycerol (L/S) ratio is greater than 2:1, the phosphatidy/glycerine (GS) appearing in the amniotic fluid is considered to be the index of the maturity of the fetal lung. Some authors carried out B-mode ultrasound examination, measured the BPD and the central diameter of the epiphysis and classified the maturity of the placenta. At the same time, they compared it with the results of laboratory examinations of the maturity of the fetal

lung in the amniotic fluid to predict the maturity of fetal lung by ultrasound. The results proved that ultrasonic examination can predict accurately the maturity of the fetal lung. Petrucha reported that in 100% in class III placenta, 97% in class II placenta, 91% in class I placenta, the L/S ratio > 2. Zhou Lin reported that when the placenta was in class I, II and III and when the BPD were greater than 8.7 cm, all the L/S values were greater than 2. Tabsh reported that when the epiphyseal diameter of the distal femur was 5 mm or when epiphyseal center of the proximal tibia was 3 mm, the pregnant woman is at least at Ú 34–35 weeks of gestation, and 94–95% had mature L/S values, indicating the maturity of the fetal lung, Tabsh also reported that if the ossifying center of the proximal tibia was Ú 5 mm in non-diabetic pregnant women, it was predicted that 100% of them would have mature L/S value.

16.3.3.3. *Prediction of the Fetal Body Weight*

Nowadays, many scholars have achieved a rather high rate of accuracy in measuring the index of many items of the intrauterine fetus, particularly the index of the soft tissue. This has been used in clinics. P. H. Person *et al.* used BPD, AD and FL as parameters to calculate the formula of the body weight of the fetus so as to calculate the normal range of growth of the fetal body weight. They used the formula on 135 pregnant women for verification. If the fetus was born 48 hours after the ultrasonic examination, the body weight at birth was 1400–4900 g. The result of the body weight calculated by formulae (1) and (2) is lower than 40 g and 62 g respectively. P. H. Person felt that the fetal growth curve was not equal to the growth curve popularly used by previous pediatricians. Its characteristic presents a shape at the late stage of pregnancy, and there is a deviation before birth,

$$\log W = 0.972 \times \log BPD + 1.743 \times \log AD + 0.367 \times \log FL - 2.646, \quad (1)$$

$$\log W = 1.321 \times \log BPD + 1.833 \times \log AD - 2.830, \quad (2)$$

where W is the body weight at birth.

Regarding the study of the prediction of the fetal body weight, many authors, nowadays, pay great attention to parameters of the soft tissues which play an important role in the accuracy of the prediction. Further research study is still in progress.

16.4. ULTRASONIC IMAGING DIAGNOSIS OF PATHOLOGICAL OBSTETRICS

16.4.1. Ultrasonic Imaging Diagnosis of the End of Development of the Embryo

16.4.1.1. *Sonogram of the End of Development of the Embryo in Early Gestation*

(a) Sonographic expression of the withering of a fertilized egg.
When the embryo stops developing during early gestation, it is called withering of fertilized egg. There may be no symptoms at the early stage, and the sonographic expressions are as follows:

(i) After 1–2 weeks of follow-up examinations, the gestation sac stops growing and the size of uterus does not change;
(ii) The outline of the section of the gestation sac is not clear, the morphology of the round circle is lost and it may become long and eggplant-shaped (Fig. 16.5);
(iii) The position of the gestation sac is lower down, mostly at the lower segment of the uterus;
(iv) Withering of the fetal bud. The flashing of the fetal heart and fetal mass reflection are not seen inside the uterus (Fig. 16.6).

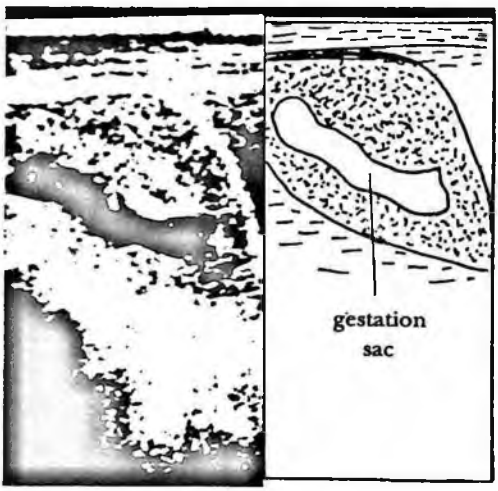

Fig. 16.5 Deformation of the gestation sac.

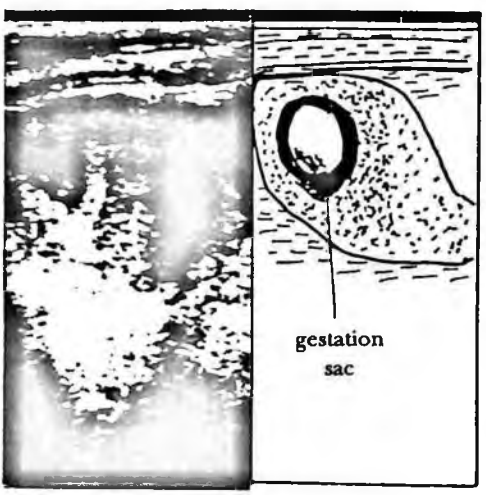

Fig. 16.6 Thickening of the wall of the gestation sac when the embryo stops developing.

(b) The sonogram of a threatened abortion in early gestation.
There is a small amount of vaginal bleeding, accompanied by a sense of descent in the lower abdomen, mild lower abdominal pain may be felt, which indicates that the embryo has begun to separate from the uterus. This is a sign of a threatened abortion. At this point of time, ultrasound may determine the possibility of survival of the fetus by the implanted position of the gestation sac, the morphology of the gestation sac and fetal motion. Sonographic expression:
(i) Enlargement of the outline of the uterus;
(ii) The intrauterine gestation sac is often at a low place and loses regularity of its margin;
(iii) If there is much bleeding, the round circle of the gestation sac is displayed incompletely, usually presenting a C-mode defect. In general, after 8–9 weeks of gestation, the flashing of the fetal heart can still be displayed, and usually the fetus can be saved to maintain gestation.

(c) Sonogram of a missed abortion
If bleeding still increases and a blood clot is found after threatened abortion has been treated, the abortion is unavoidable and is called inevitable abortion. If the dead fetus is retained in the uterine cavity for over two months, it is clinically called a missed abortion. Blood gradually infiltrates between the villus and decidua of the embryo, and amniotic fluid is absorbed. The fetus becomes soft and necrotic due to the encapsulation of clotting blood, causing deformation of the fetus. Sonographic expression:
(i) There is marked deformation or loss of the gestation sac, and the flashing of the fetal heart is not seen;
(ii) Enlargement of the uterus does not coincide with the gestational weeks, but is smaller compared to a the uterus of a normal person with equal gestational weeks;
(iii) The fetus and placenta lose their normal morphology, expressing scattered, disordered echogonic dots or hyperechogenic mass, similar to the sonogram of a hydatid mole. Both should be differentiated.

16.4.1.2. *Sonogram of a fetus which died in the uterus during the metrisemester and late gestation*

Clinically, during metrimester gestation (refering to 13 weeks after gestation), bleeding stops after there has been a large amount of vaginal bleeding or after treatment of threatened abortion. Whether the fetus is still living in the uterus is rather difficult to diagnose clinically, particularly in late gestation. Even after the fetus has died in the uterus for a considerable length of time, it is difficult to jude the survival of the fetus. Ultrasonic examination may reveal a more accurate diagnosis. The sonographic expressions are as follows:

(a) The size of the uterus does not coincide with the week of gestation, even the volume of the uterus is constricted;
(b) There is loss of fetal heart beat and fetal motion;
(c) The outline of the fetal head presents a double-line change, or the overlapping of cranial bones are like piling titles or a long sac (Fig. 16.7);

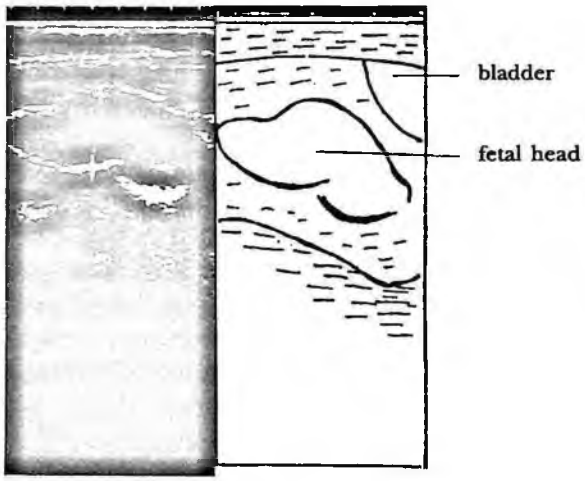

Fig. 16.7 Dead fetus in the uterus, the cranial bone of the fetal head overlapping like piling of tilts.

(d) Due to the separation and edema of the subcutaneous tissues, the fetal head and fetal body have double layer echoes, or present concentric-circle variations.

16.4.2. Ultrasonic Diagnosis of Prolonged Gestation

Pregnant women with normal menstruation but with gestation greater than 42 weeks are said to have prolonged gestation. If the placental function is normal in prolonged gestation, it will not effect the development of the fetus. The fetus may be too big or the fetal head too hard, which will induce a high rate of difficult labours. If the placental function is decreased, it will cause insufficient supply of oxygen and nutrition. This will affect the development of the fetus. Both conditions will increase the mortality rate of perinatal infants. By using B-mode ultrasound, through the examination of the maturity of the fetus, the placenta, and the conditions of the amniotic fluid, one may discover high-risk pregnancies early and thus lower the rate of mortality in prenatal infants. The ultrasonic expressions of prolonged gestation are as follows:

(a) Macrosomia, postmature infant
Prediction of the fetal body weight by many parameter measurement is conducted. The incidence rate of macrosomia is high in prolonged gestation.

(b) Ageing placenta
Most placenta are in class III of prolonged gestation. Literature reports show that it is as high as 92.8%. If the placenta is still class 0 or class I at 42 weeks after gestation, the fetal age is doubtful. An ageing placenta easily induces oligoamnios. But the class of the placenta has no distinctive relationship with the prognosis of the fetus;

(c) Oligoamnios
This is the most important index of diagnosis of prolonged gestation. Oligoamnios occurs when the deepest of the amniotic fluid is less than or equals to 3 cm. Rayburn reported that the incidence rate of prolonged gestation complicated with oligoamnios

may reach 83%. It is the clinical feature of ageing of the placenta and fetal membranes. The incidence rate of fetal distress in the uterus, postmature infants, suffocation of new-borns and operative delivery in oligoamnios is much higher than that in the normal amniotic fluid. It should be treated immediately in order to retain the pregnancy. In general, prolonged gestation with oligoamnios begins to appear in the 40th week. Therefore, an early examination is necessary to improve the prognosis of the high-risk fetus.

16.4.3. Ultrasonic Imaging Diagnosis of Extrauterine Gestation

Extrauterine gestation refers to the implantation and development of the fetal egg in the organ outside the uterus, i.e. ectopic gestation. The incidence rate is about 2–3%. It may occur in the fallopian tube, ovary, abdominal cavity, broad ligament and uterine cervis. Among these, 95% are tubal pregnancies, which usually rupture in the 6–12th week of gestation. The clinical expressions are sudden severe pain in the lower abdomen, vaginal bleeding, the occurrence of shock after amenorrhea, and other signs. The sonographic expressions depend on different positions of occurrence and the course of the disease which is separately described as follows:

16.4.3.1. *Unruptured Tubal Pregnancy*

Clinically, there is a history of amenorrhea, and discomfort in the lower abdomen accompanied by a small amount of vaginal bleeding. The sonogram reveals an enlargement of the uterus but no gestation sac is found. The intrauterine echo is disorderly and echoes of a cystic-like mass surrounding the uterus may be displayed. This is known as intra-tubal pregnancy. One may also find that the uterine cornu at the side of the pregnant fallopian tube has increased in width. Sometimes, one may find a flashing fetal bud.

16.4.3.2. *Ruptured Tubal Pregnancy*

There are signs of various degree of bleeding, if it is a small amount of bleeding, one can find blood accumulated in the retrouterine excavation, forming a bloody mass in the pelvis. The uterus is enlarged and there are disorderly echoes. If there is a large amount of bleeding, the liquified dark areas can be examined in the pelvic cavity and around the umbilicus. Also, one may find echoes of a floating intestinal tract.

16.4.3.3. *Old Ectopic Pregnancy*

The volume of the uterus is enlarged or normal, the outline is clear and one may find echoes of irregular shapes posterior to the uterus. Its internal echogenic dots are disorderly, and sometimes one may find a rather big mixed mass of fully-filled, liquified, dark area. Floating echogenic dots and a hyperechogenic mass can be found, similar to cystic teratoma of the ovary, which should be differentiated from old ectopic pregnancy.

16.4.3.4. *Ectopic Pregnancy in Other Positions*

Examples such as abdominal pregnacies are rare as are secondary abdominal pregnancies. If it is a ruptured tubal pregnancy, the fertilized egg enters the broad ligament and is implanted there and the gestation may carry on. It is rather difficult to diagnose clinically. The sonogram can display a mild enlargement of the uterus and an increase in the intrauteine echogenic dots. If the pregnancy stretches over 12 weeks, echoes of the fetal head, fetal body and placenta can be displayed. But as the other structures of the fetal body and fetus often mingle with the viscera of the materal abdominal cavity, differentiation is difficult. Even the relationship of the position between the light circle of the fetal head and the uterine cavity is not easy to identify. At this point of time, under strict local sterlization, one may instill proper amounts of normal saline into the uterus through the uterine cervix. This can help to differentiate uterine pregnancy from abdominal pregnancy.

16.4.4. Ultrasonic Imaging Diagnosis of a Multiple Pregnancy

Multiple pregnancy means there are two or more embyros or fetus growing during one gestation. Most of them are binovula pregnancies, in which about 75–80% are binovular twins and 20–25% are uniovular twins. The former has two fertilized eggs implanted in different positions of the uterus, therefore there are two placenta and fetal sac. The latter is formed by the division of a fertilized egg. If it has divided 24 days after fertilization, each embryo will have its own amniotic cavity; if it has divided 8 days after fertilization when the amniotic sac has already been formed, these two embryos will coexist in one amniotic cavity. Therefore, the sonograms of early multiple gestation vary and should be observed carefully.

16.4.4.1. *Sonogram of An Early Multiple Pregnancy*

(a) There is marked enlargement of the uterus.
(b) One may find two or more round light circles. Flashing of two fetal hearts can be seen after more than 6–7 weeks of pregnancy (Fig. 16.8). In the examination, attention should be paid to the sections in many directions. As far as possible, let the two gestational sacs be displayed in one image (displayed in one section).

16.4.4.2. *Sonogram of the Mid, and Late Stages of a Multiple Pregnancy*

(a) There is marked and rapid enlargement of the uterus.
(b) Two or more echoes of the fetal head and fetal body can be displayed inside the uterus. One may find pulsation of each fetal heart. Diagnosis of a multiple pregnancy is reliable if two fetal heads or pulsation of two fetal hearts are found in one section. Sometimes, the two fetal heads are far apart, hence they should be examined separately. Take note of the direction of the probe in order to avoid repeated displays (namely one fetal head will display two images). Careful differentiation should be made between multiple gestation and pregnancies producing triplets or more in the late stages of pregnancy (Fig. 16.9).

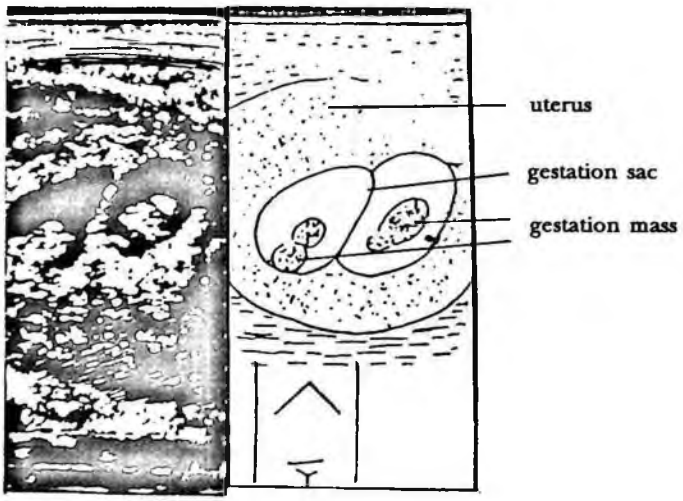

Fig. 16.8 Early stage of binovular pregnancy.

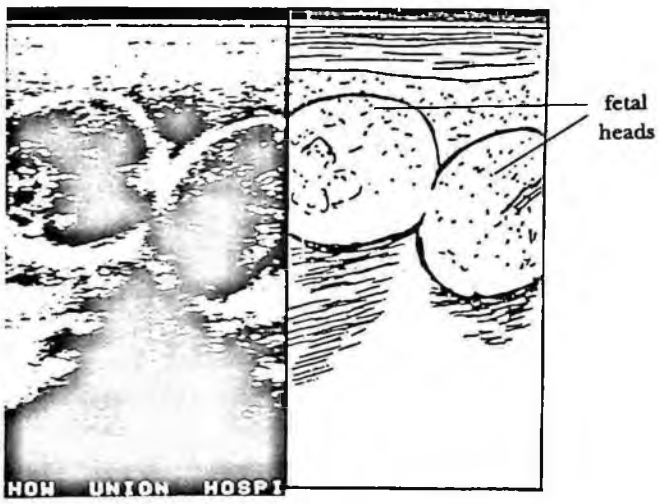

Fig. 16.9 Binovular pregnacy in metrisemester pregnancy.

(c) The depth of the amniotic fluid is often greater than that of a normal uniovular pregnancy of the same period.
(d) The placenta has a big area. Uniovular pregnancy often has a rather big placenta, but a binovular pregnancy may display two placentas attached to the wall of the uterus.

It is worth pointing out that in the early stage of pregnancy, women being diagnosed with binovular pregnancy by ultrasound, (even in metrimester pregnancy), and women diagnosed with binovular pregnancy or multiple pregnancy, have only the fetus during delivery, or a number less than that known in the previous diagnosis. This is because the fetus in a multiple pregnancy dies during development. Out of the 30 cases reported with early diagnosis of

binovular or multiple pregnancy, only 50% maintain the original diagnosis during the delivery. Therefore, early diagnosis for multiple pregnancy by ultrasound require many follow-up sessions to ascertain the conditions of development.

16.4.5. Ultrasonic Imaging Diagnosis of Uterus Duplex and Uterus Bicornis Pregnancy

In a uterus duplex or uterus bicornis pregnancy, the fertilized egg is often implanted only in one uterus or in one cornu of the uterus. A uterus or cornu of the uterus without an implanted fertilized egg will enlarge along with the physiological changes of pregnancy.

Sonographic expression:

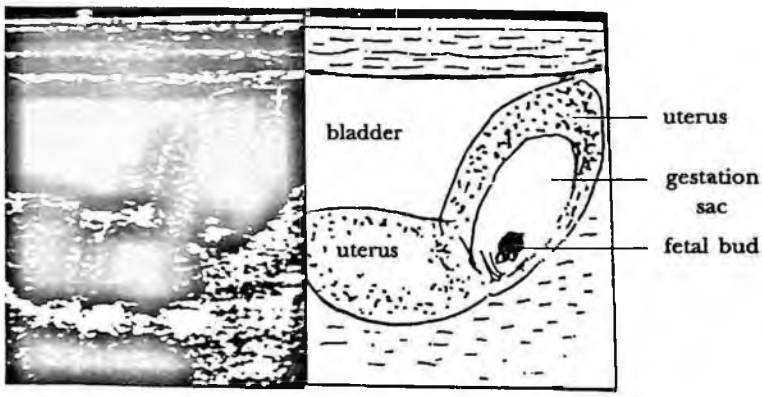

Fig. 16.10 Uterus duplex gestation on one side of the uterus.

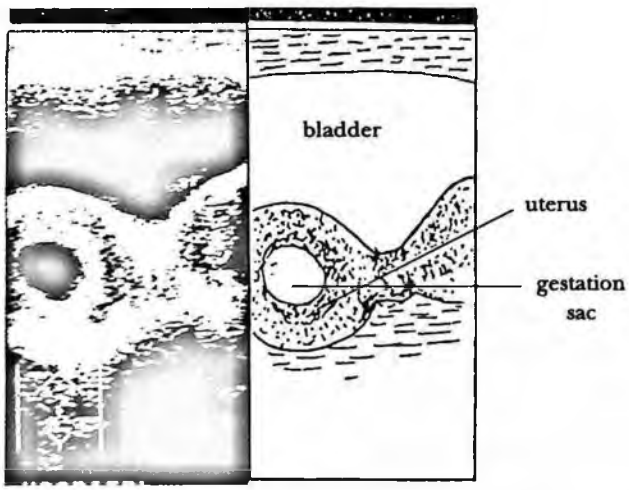

Fig. 16.11 Uterus duplex — gestation on one side of the uterus.

(a) The heart can be seen inside one enlarged uterus; the other uterus or cornu of the uterus is also slightly enlarged the internal echo enhancement is disorderly (Figs. 16.10 and 16.11);
(b) In the mid and late stages of pregnancy, echoes of the fetal head and fetal body can be found in the gestational side, while the other side of the uterus or uterine cornu express echoes connecting with the solid mass, which is quite similar to a pregnancy complicated with myoma of the uterus. This is rather difficult to diagnose. It should be carefully examined from many directions in order to understand its outline and its relationship with the uterine cervix. Certain cases of uterus duplex and uterus bicornis can only be ascertained after delivery.

16.4.6. Ultrasonic Imaging Diagnosis of a Hydatid Mole

A hydatid mole is a transitional hyperplasia of trophocyte in the chorionic membrane. According to the degree of hyperplasia, with or without villus, and the ability to invade, it is divided into hydatid mole, malignant hydatid mole and choriocarcinoma. A hydatid mole is caused by the hyperplasia of a trophocyte and villus interstial edema, causing the villus to become a vesicle with varying sizes. The small one is several millimeters, the bigger one is 2–3 cm. The incidence rate in gynecology patients is about 0.85%. When the vesicular tissues exceed the uterine cavity and invade the muscular layer or metastasize to another organ, it is called a malignant hydatid mole, and there is a hidden danger of chorioepithelioma. Due to the action of chorionic gonadotropin, about 50% of the patients may develops cystic enlargment in the ovary with serous fluid contained in the cyst called a lutein cyst, which may reach 10–20 cm. Ultrasonic imaging diagnosis of the hydatid mole has a rather high sensitivity and idipathy.

Sonographic expression:

(a) There is marked enlargement of the uterus, but a minority of patients with hydatid mole have the size of their uterus conciding with or smaller than the week of pregnancy;
(b) There are no gestatation mass and placenta in the uterus. Inside the uterus, one may find disorderly echoes with enhancement of echogenic dots, forming diffusive "snowing-like" echoes. Modern apparatus with high resolution can be used to find round echoes of various sizes or honeycomb-like echoes (Figs. 16.12 and 16.13).
(c) Besides the honeycomb echo area, the echo of the gestation mass and fetal heart can still be found in a part of the hydatid mole. But there is no clear echoes of the placenta and amniotic dark area;
(d) If accompanied by an ovarian lutein cyst, one may find round or oval dark areas surrounding the uterus. Most of them are polylobulated structures, and are often examined in the rectouterine fossa or superior to the fundus of the uterus;
(e) Degenerative hydatid mole. One may find a normal-sized or constricted uterus. Disorderly echogenic dots spread throughout the uterine cavity. Without echoes of the fetus and placenta seen in the uterine cavity, it is easily mixed up with the sonogram of a missed abortion. But in a missed abortion, disorderly echogenic dots are mostly concentrated in the center of the uterine cavity, the echogenic dots surrounding the uterine cavity are scarce or absent.

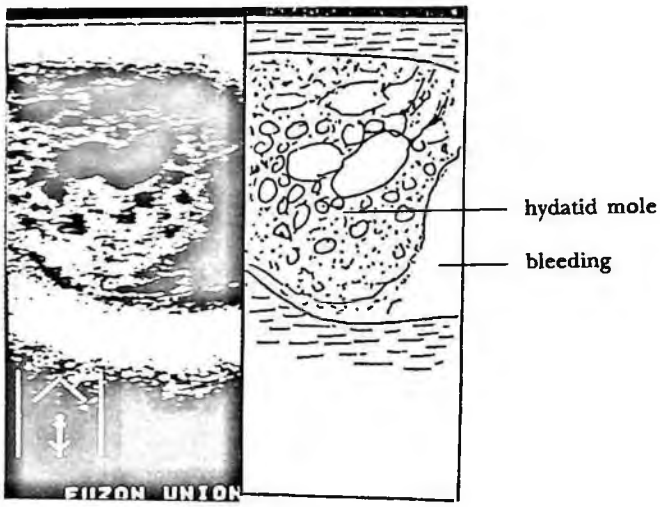

Fig. 16.12 Sonogram of a hydatid mole.

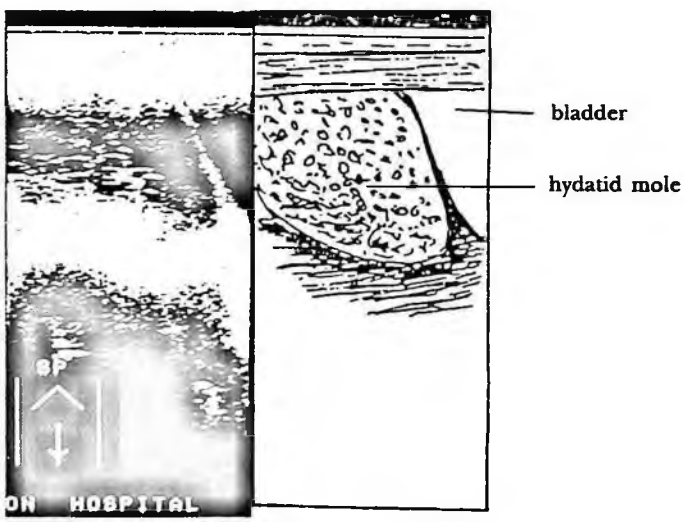

Fig. 16.13 Hydatid mole complicated with intrauterine hemorrhage.

16.4.7. Ultrasonic Imaging Diagnosis of Placenta Previa

Placenta previa is a serious complication of pregnancy, and it is one of the main causes of hemorrhage at the late stage of pregnancy. The rate of incidence in clinics is 0.5–1%. It is due to a fertilized egg being implanted at the isthmus of the uterus or nearby, and along with its growth and development, it causes the placenta to be situated at, or covering, the internal orifice of the uterine cervix or it vicinity, hence forming the placenta pelvia. According to the relationship between the position of the placenta and that of the internal orifice of the uterine cervis, the placenta previa is divided into 4 types: (a) Central placenta previa, (b) Partial placenta previa, (c) Marginal placenta previa, and (d) Low placed placenta.

16.4.7.1. *Central Placenta Previa*

When the longitudinal section above the pubis is taken, one may find the placenta completely covering the internal orifice of the uterus. Between the fetal head and internal orifice of the uterine cervix, there is a layer of echogenic dots with echoes, that look like a crescent, and is about 2–3 cm thick. Between the fetal head and placenta, one may find an amniotic dark area (Figs. 16.14 and 16.15).

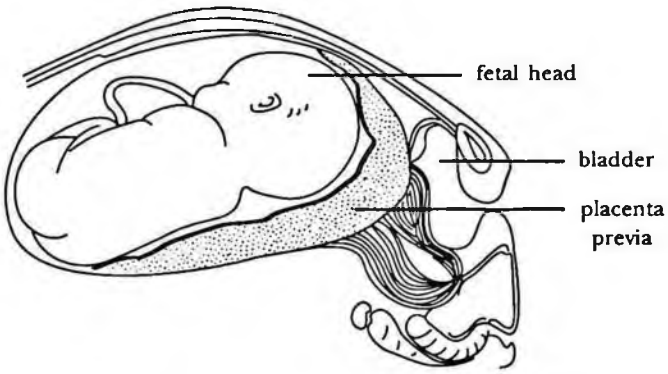

Fig. 16.14 Sketch map of the placenta previa.

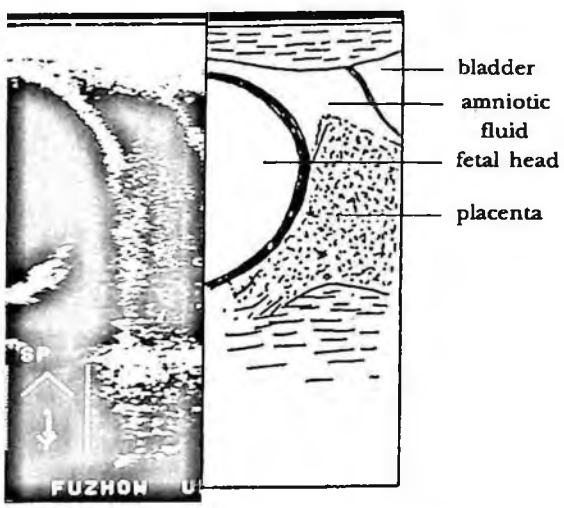

Fig. 16.15 Central placenta previa.

16.4.7.2. *Partial Placenta Previa*

The position of the placenta is further divided into the anterior wall and posterior wall partial placenta previa.

(a) Anterior wall partial placenta previa
From the longitudinal section of a sonogram of the placenta at the anterior wall of the uterus, extending to the lower segment of the uterus, can be found, and part of the placenta covers the internal orifice of the uterine cervix. Between the light circle of the fetal head and the villus laminal is an amniotic dark area. But this dark area is not clear in breech presentation;
(b) Posterior wall partial placenta previa
Taking a longitudinal section above the pubis, no echoes of the placenta are found at the anterior wall of the uterus. The light circle of the feal head is very close to the bladder wall. Echoes of the placenta and villus lamina only appear at the posterior lateral wall, and part of it covers the internal orifice of the uterus. In the sonogram, a triangular dark area is formed by the fetal head, bladder and villus lamina. It is an important sign showing a partial posterior wall placenta previa.

16.4.7.3. *Marginal placenta previa*

It is also divided into marginal anterior wall and posterior wall placenta previa. The sonographic expression is similar to that of the partial placenta previa. The margin of the placenta extends only to the nearby internal orifice of the uterine cervix, but does not cover it. The margin of the placenta is displayed clearly.

16.4.7.4. *Low Place Placenta*

The margin of the placenta does not reach the internal orifice of the uterine cervix but is very close to it. According to its position, it is also divided into the anterior wall and posterior wall low place placenta.

In general, ultrasonic imaging diagnosis of placenta previa has a high accuracy. It may be discovered in a prenatal ultrasonic examination, hence altering the situation in the past, in which the clinical diagnosis was done only when there was vaginal bleeding during late pregnancy. But in ultrasonic diagnosis of placenta previa, the following items should be noted in order to improve its accuracy:

(a) Low place placenta or placenta covering the internal orifice of the uterus in mid pregnancy should not be diagnosed too early as in placenta previa. With the increase in the month of pregnancy, the enlarged uterus placenta may be displaced upwards;
(b) When examining the placenta previa, particularly in the case of posterior wall placenta previa, the bladder should not be over-filled, this is to avoid a posterior displacement of the cervix, resulting in a "false placenta previa". Medium filling will be appropriate;
(c) In breech presentation, the fetal body or thigh should not be mistaken for the placenta previa;
(d) Local contraction of the uterus during parturition is also easily mistaken for the placenta;
(e) The posterior wall placenta previa is often covered by the fetus, therefore it is difficult to display. At this point of time, one may take the decubitus position or push the fetal head slightly upwards to display the placenta more clearly. Also, according to the position of the upper end of the placenta and the normal average length of a full-term

placenta (20 cm), one may estimate the position of the lower end of the placenta or the degree which the internal orifice is covered.

16.4.8. Ultrasonic Imaging Diagnosis of Early Separation of the Placenta

The early separation of the placenta refers to partial or complete separation of the normal position of the placenta from the uterine wall before the birth of a child after the 20th week of gestation. It is also one of the serious complications of late pregnancies. It may induce severe hemorrhage, infection, decrease in fibrinogen, acute renal failure, and other serious complications. Clinically, it is often seen during late pregnancies. It starts with a sudden continuous pain in the lower abdominal, accompanied with or without vaginal bleeding. About 80% of them are external hemorrhage, i.e. having vaginal bleeding followed by intrauterine hemorrhage; 20% are internal hemorrhage, with only intrauterine hemorrhage without vaginal bleeding. Hematoma is formed between the placenta and uterine wall.

Sonographic expression:

(a) An echoless dark area appears between the placenta and uterine wall (under normal conditions these two are in close contact). The dark area is irregular and disorderly echoes of echogenic dots may be found. In mild cases, the dark area is less than 1/3 of the placental surface, in serious cases, it is bigger than 1/3.
(b) Fetal surface of the placenta bulges into the amniotic cavity.
(c) Localized placenta may thicken, one may find floating echogenic dots in the amniotic fluid due to exudation of blood.
(d) Serious early separation of the placenta is often accompanied by the death of the fetus in the uterus. At this point of time, fetal heart and fetal motion disappear.
(e) During early separation of the placenta at the anterior wall, the fetus is often close to the posterior wall of the uterus. During the early separation of the placenta at the posterior wall, the fetus is close to the anterior wall of the uterus. Ultrasonic diagnosis of the early separation of the placenta should be differentiated from the following conditions:
    (i) Uterine myoma accompanied with pregnancy: Sometimes, one may find a tumor mass causing a round oppression area of the uterine wall or placenta, but its margin is regular with solid echoes, while for a separation of the placenta, it is a liquified dark area;
    (ii) Polycystic or calcified area of placenta at late pregnancy: it is a dark area of blood sinus of the placenta during late pregnancy, but the dark area is located in the center of the placenta or the calcified light circle forms the dark area. Both are not near the position between the placenta and uterus. Also, the villus lamina of the placenta does not protrude into the uterine cavity.

16.4.9. Tumor of the Placenta

The main ones are chorioangioma and placental cyst. The former is a benign capillary hemangioma, presenting a lobulated or nodular shape. It occurs mostly in the fetoplacental face of the placenta, with different size. The placental cyst is derived from the degeneration

of the liquified area of the fibrinoid inside the placental septum, or in the spaces of the villus. It is often seen in the fetoplacental face of the placenta and may also be found in the deep portion of the placenta. Its size varies from several millimeters to several centimeters.

16.4.9.1. *Sonographic Expression of Choriangioma*

(a) Within the placenta, one may find low-level echoes similar to the round or lobulated mass echoes. Its surface is smooth.
(b) Within the tumor, one may find coarse, big echogenic dots or irregular dark areas, i.e. blood sinus, inside the hemangioma. Parallel light bands of the cross-section of the blood vessels may also be found.

16.4.9.2. *Sonographic Expression of Placental Cyst*

(a) Inside the placenta one may find a round or oval-shaped echoless dark area.
(b) The cystic wall is thin, and the boundary is clear and smooth. There is a marked enhancement effect posterior to the cyst. The size varies from several millimeters to several centimeters.

16.4.10. Ultrasonic Imaging Diagnosis of Abnormality of the Amniotic Fluid

It includes hydroamnios and oligoamnios. The amount of amniotic fluid gradually increases with the advancement of pregnancy. Under normal conditions, the amount of amniotic fluid is the greatest during the 7th month of pregnancy — about 1000–1500 ml. Then it gradually lessens. The average amount of amniotic fluid is 500–1000 ml at full term. At full-term pregnancy, if the amniotic fluid is over 2000 ml, this means hydroamnios has occurred. If the amniotic fluid is less than 300 ml, this means oligoamnios has occurred (mostly in prolonged pregnancies). Clinically, the amount of amniotic fluid in the primipara may be less, and move in multipara. Hydramnios is often accompanied by multiple gestation, fetal deformity or toxemia of pregnancy. When conducting an ultrasonic examination, one should take note of the following:

(a) While examining the depth of the amniotic fluid, the probe should be placed perpendicular to the horizontal line, then search for the biggest area of the amniotic fluid, the anteroposterior diameter is measured;
(b) Whether it is complicated with multiple gestation or fetal deformity.

16.4.10.1. *Sonographic Expression of Hydramnios*

(a) There is marked enlargement of the uterus exceeding the month of pregnancy.
(b) A stretch of liquified area is seen with the uterus, its largest anteroposterior diameter is bigger than 10 cm.
(c) The fetus occupies a small part of the uterus only, and the fetal extremities are like a mass of cotton, floating in the amniotic fluid (Fig. 16.16).

(d) The thickness of the placenta is small and clearly displayed.
(e) Usually, it is complicated with multiple gestation or an abnormal fetus. Acute hydroamnios often occurs in the mid stage of pregnancy, while chronic hydroamnios is often seen in the late stage of pregnancy.

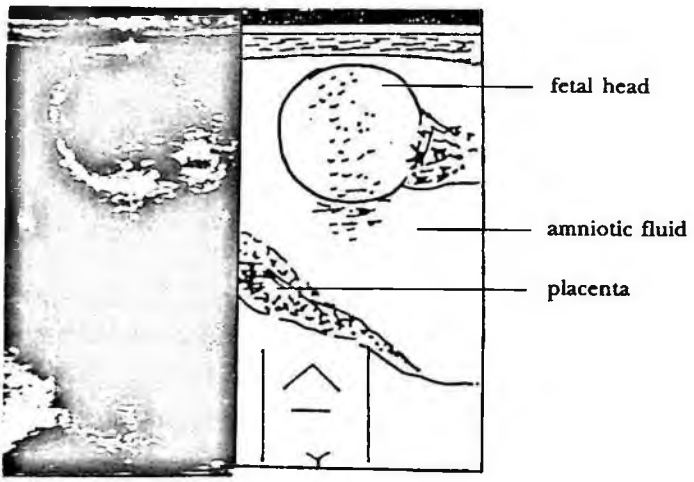

Fig. 16.16 Hydroamnio, fetus floating in the amniotic fluid.

16.4.10.2. *Sonographic Expression of Oligoamnios*

(a) The size of the uterus is smaller than the month of pregnancy.
(b) There is marked shrinkage of the dark area of the intrauterine amniotic fluid. By using many sections, the big amniotic dark areas still cannot be examined. The largest anteroposterior diameter of the amniotic dark area is less than 2–4 cm.
(c) The outline of the fetus and placenta are often not clearly displayed. For the diagnosis of oblignoamnios at different stages of pregnancy, one may use the depth of the amniotic fluid (anteroposterior diameter of amniotic dark area) as reference.
Early pregnancy — the anterposterior diameter of the amniotic dark area is less than 2 cm.
Mid pregnancy — the anteroposterior diameter of amniotic dark area is less than 3 cm.
Late pregnancy — the anteroposterior diameter of the amniotic dark area is less than 2 cm.

16.4.11. Ultrasonic Imaging Diagnosis of Fetal Malformation

Using ultrasonic imaging to monitor the development and growth of the fetus and to discover fetal malformation early plays an important role in eugenics. Nowadays, the methods used to define fetal malformation are x-ray examination, analysis of maternal blood and composition of amniotic fluid, amniotic cell culture and some other biochemical examinations. But the positive rate is low, the methods are complicated and the practical value in clinics is poor. However, contemporary ultrasonic imaging can be used to clearly display the outline and

viscera of the fetus, conveniently observe the development and growth the fetus, and to discover many malformations early.

16.4.11.1. *Hydrocephalus of the Fetus*

Due to congenital development of the nervous system, too much spinal fluid accumulate in the intracranial cavity. Common causes are stenosis of the central canal of the cerebrum, formation of the septum in the cerebrum or adhesion and stenosis at the exit of the fourth ventricle, leading to decrease in the circulation of the spinal fluid resulting in too much spinal fluid being retained in the intracranial cavity inside or outside the ventricle. The least is about several tens of millilitres, the most about several thousand millilitres. At the point of time, the ventricle expands, the cranial bone becomes thinner and soft, and is often accompanied by spinal bifida (seen in about 1/3 of cases of fetal hydrocephalus).

Sonographic expression:

(a) In early or mild hydrocephalus one can only find an increase in the width of the lateral ventricle, both sides may or may not be equal. The BPD is often within the normal range. Under dynamic observation, the BPD increases by 3 mm each week, the transverse diameter is bigger than 15 mm on one side of the lateral ventricle, or the lateral ventricle ration (LVR) is bigger than 0.36. All of these indicate the occurrence of hydrocephalus.
(b) In severe cases of hydrocephalus, the light circle of the cranial bone loses its normal form, presenting a squarish round shape. The cranial plate becomes thinner, most parts inside the cranium present liquified dark areas, or one may find the solid echoes of the brain being oppressed to the bottom of the cranium. At this point of time, the BPD is markedly increased, usually over 10 cm;
(c) The fetal head and fetal body are not proportional.
(d) If complicated with hydramnios, the anteroposterior diameter of the amniotic fluid increases.
(e) If complicated with spinal bifida, one may find an interruption along the spinal column.

16.4.11.2. *Acculumation of Fluid in the Body Cavity of the Fetus*

The fetus may have accumulated of fluid in every part of the body cavity, it may occur in a single position or multiple position.

(a) Fetal ascites
Inside the fetal abdomen one may find a liquified dark area encircling the liver, one may also find the intestinal tract floating in the dark area (Fig. 16.17) and shifting change of the ascites. Fetal ascites should be differentiated from hydramnios. The latter may have a stretch of liquified dark area inside the uterus, but no liquified dark area inside the fetal abdomen. Owing to the abdominal wall of the fetus, one must examine carefully to ascertain whether there is fetal ascites.
(b) Fetal hydrothorax
In a section of the chest, one may find a rather wide band-like echoless dark area between the thoracic wall and the lungs.

(c) Hydrops in other positions

In pericardial effusion of the fetus, one may find a circular echoless dark area in the pericardial cavity surrounding the heart. In hydrocele of the tunica vaginalis of the fetus, one may find enlargement of the scrotum on the crown section of the scrotum. The two testicles present a oval hyperechogenic mass of median echo, and an echoless dark area may be found inside its surroundings (Figs. 16.18 and 16.19). In subcutaneous edema of the fetus, one may find enhancement of the echoes of the skin and the subcutaneous tissues in the whole body. At its posterior, one may find an echoless dark band, often accompanied by ascites and hydrothorax.

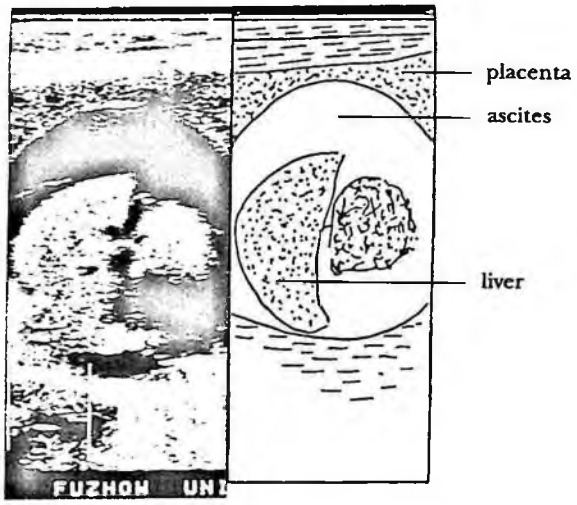

Fig. 16.17 Large amount of ascites of the fetus.

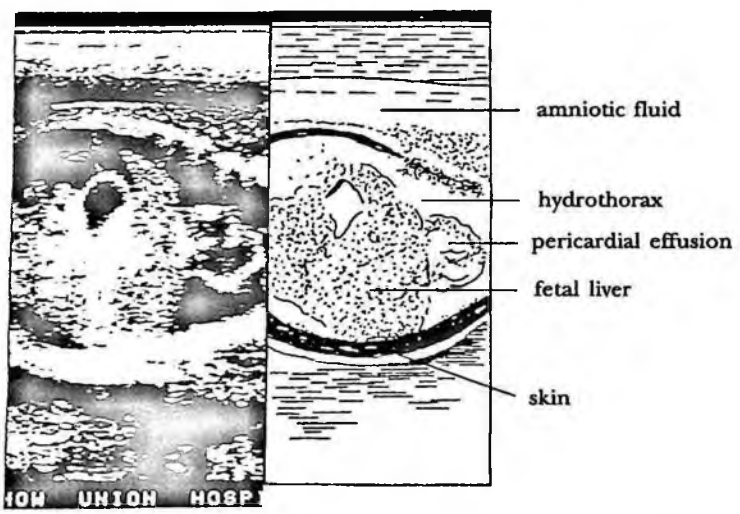

Fig. 16.18 Hydrothorax and pericardial effusion of the fetus.

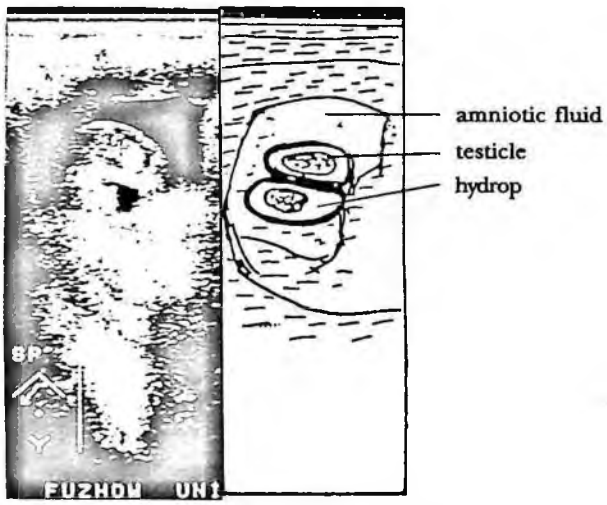

Fig. 16.19 Hydrocele of the tunica vaginalis of the fetus.

16.4.11.3. *Anencephalus*

It is a common congenital malformation of the fetus mainly due to the lack of a skull to cover the cerebrum, usually accompanied by spinal bifida. The brain becomes degenerated and atrophied due to a lack of protection by the skull, leading to secondary absence of the brain tissues. It is usually accompanied by hydroamnios.

Sonographic expression (Fig. 16.20)

(a) 15 weeks after gestation, no complete cranial light circle of the fetal head is seen. The echo of brain tissues is not found as well. One may find only the echo of a half circle of the face.

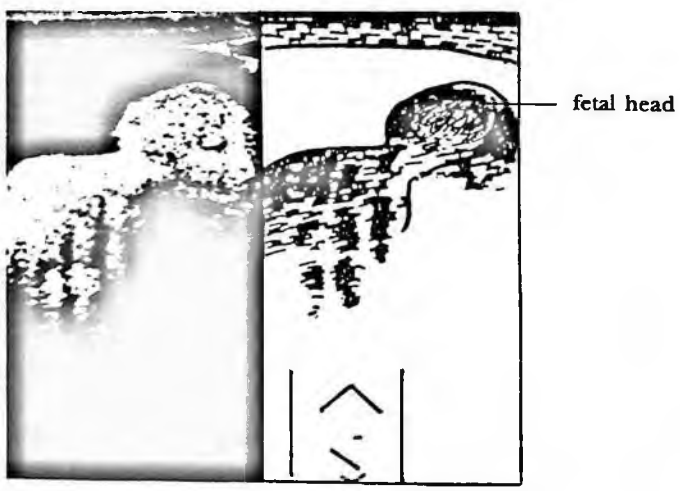

Fig. 16.20 Anencephalus, the cranium presents half-round, hydramnios.

(b) It is accompanied by hydroamnios. The fetus is often located at the posterior wall of the uterus. If the fetal head is close to the internal orifice of the uterus, the display will not be clear. Hence, it should be examined by changing the body position.
(c) If complicated with spinal bifida, an interruption to the spinal vertebral column will be seen.

16.4.11.4. *Spinal Bifida*

It is due to the absence of the median line of the vertebral column, a cleft is formed by incomplete union of several laminae of successive vertebra posterior to the vertebral column. About 80% are found in the lumbosacral vertebrae. They may be accompanied by bulging out of the spinal meninges or meningomyelocele. Usually, the fetus suffers from hydrocephalus or hydramnios.

Sonographic expression:

(a) After displaying the fetal head, the probe is moved from the fetal head to the direction of the trunk for scanning. One may find abnormalities in the local arrangement of two rows of bead-like vertebral strong echoes. An irregular curve is presented, the space between the beads is increased or absent, causing an interruption to the bright bead-like light band, or presenting an irregular figure of "8" light band.
(b) A cystic, bulging substance may be found at the place where the bead-like light band is interrupted, and it may be found floating in the amniotic fluid.
(c) It is usually accompanied by the anencephalus or hydramnios.
(d) If it is accompanied by meningocele, one can usually find a cystic mass in the sonogram, which is ball-like and bulges into the amniotic dark area near the posterior fontanel of the fetus, approximately to the occipitale. In general, the echo of the cystic wall is fine and smooth, while inside the cyst is an echoless dark area. Solid echoes are found if there is bulging of the brain parenchyma.

16.4.11.5. *Eversion of Fetal Viscera*

The fetal viscera bulges out of the body cavity and floats in the amniotic fluid. At this point of time, the echo of the thorax or abdominal wall is hazy and unclear. In eversion of the thoraic viscera, one may find the heart present as a round solid mass pulsating in the dark, area and surrounding it are the amniotic dark areas. In eversion of the abdominal viscera, one may find the intestinal tract and bladder floating in the amniotic fluid. In total eversion of fetal viscera, one may find an absence of brain tissues in the fetal head, presenting an irregular, echosless dark area (Fig. 16.21).

16.4.11.6. *Congenital Cardiac Malformation of the Fetus*

It is one of the most commonly seen type of fetal congenital malformation. It may be related to the lack of fetal heart development or to wrong axial rotation such as translocation of the big blood vessels and tetralogy of Fallot. Congenital cardiac malformation of the fetus may be due to a viral infection in the mother during the gestation period, (particularly in the first

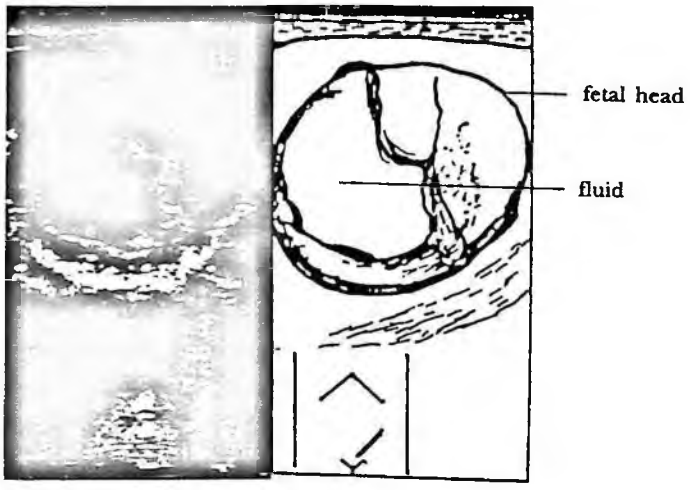

Fig. 16.21 Sonogram of a cranium of total eversion of fetal viscera.

three months), such as rubella and infuenze, the intake of sedatives or large amounts of quinine during early gestation, the mother suffering from anoxia complicated with asthma, or by the effect of radiation on the mother. The most common ones are ventricular septal defect, tetralogy of Fallot and patend duct artery. They occupy nearly 50% of all congenital cardiac malformation.

Sonographic expression

(a) Enlargement of the heart
A normal anteroposterior diameter of a fetal heart is less than 1/2 of the anterioposterior diameter of the thorax. If the anteroposterior diameter of the fetal heart is 1/2 greater than the thoraic diameter, it indicates an enlargement of the heart, and usually there is congenital malformation.

(b) Arrhythmia of the fetal heart or abnormal proportion of internal diameter of the left and right ventricles
In normal mid and late stages of pregnancies, the ratio of the fetal left and right ventricle is 1:1. The ratio is abnormal in the case of malformation, and will induce premature beats, artrioventricular block, bradycardia or tachycardia. Usually, these indicate congenital cardiac malformation.

(c) In late pregnancy one may diagnose ventricular defect, atrial defect, tetralogy of Fallot and single ventricle. But sometimes it is rather difficult, hence it is should be carefully combined with M-mode ultrasonic cardiogram.

(d) Pericardial effusion
In the pericardial cavity surrounding the heart one may find echoless dark areas.

According to signs such as the enlargement of the fetal heart, abnormal heart rhythm and heart rate, and abnormal ratio of the size of the left and right ventricle, the B-mode ultrasonic cardiogram and M-mode ultrasonic cardiogram should be used to further understand the continuity of each valve with the artioventricular septum, and some congenital cardiac malformation may be found.

16.4.11.7. *Other Malformations*

Take the pathologic changes of the kidney as an example. After 20 weeks of pregnancy, the sonogram of a normal fetus should display the kidney along the two sides of the vertebral column. If the volume of the kidney is increased, the pelvic echoes are separated and the space is filled by echoless dark area, this is called hydronephrosis. If the volume of the kidney is markedly enlarged and numerous small, round dark areas are seen inside, this means that the kidney is polycystic. This is usually accompanied by many differently-sized echoless dark areas in the liver which means that the liver is polycystic.

Malformations of the intestinal tract such as stenosis or atresia at any portion of the intestinal tract will cause dilation at the proximal end. Malformations such as stenosis of the distal segment of the duodenum will cause marked dilation of the duodenum, and two echoless dark areas will be found in the upper abdomen of fetus, i.e. the dark area of the stomach and the duodenum. When atresia of the distal end of the large intestine occurs, echoless dark areas of different sizes may be found in the abdomen of the fetus, and the morphology will be changed with intestinal peristalsis of the fetus (Figs. 16.22 and 16.23).

16.4.12. Teratoma

Fetal teratoma is derived from three embryonic layers of placenta tissues. It may be found in many positions of the fetal body, such as the brain, retroperitoneum, mediastinum, pelvic cavity, neck and precoccygeal region. The sonogram may show the volume of the tumor to be rather big, its internal part often presents mixed echoes and strong echogenic patches, or a hyperechogenic mass may be found.

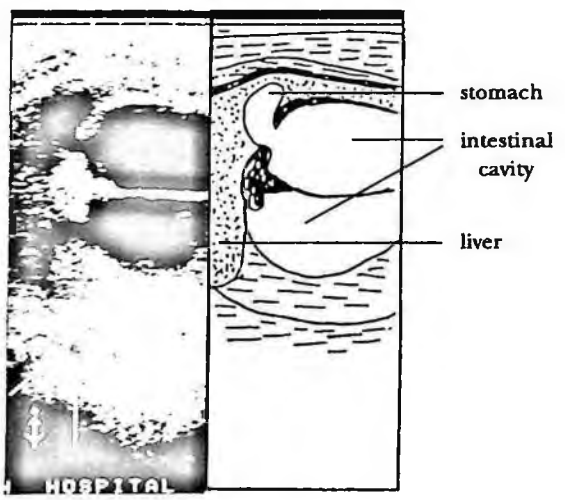

Fig. 16.22 Dilatation of the intestinal tract in imperforate anus of the fetus. The stomach is in communication with the intestine.

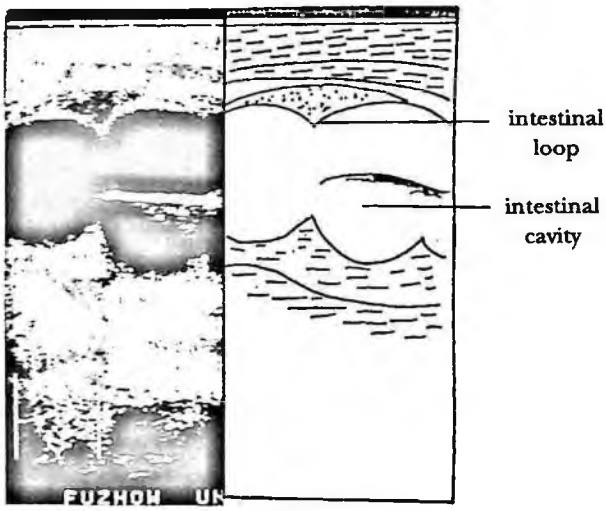

Fig. 16.23 Dilatation of the intestinal tract in imperforate anus of fetus. The intestinal loop can be seen.

16.4.13. Hemolytic Disease

This is an immunological disease of the isotype produced by incompatible blood groups of the mother and child. What the fetus inherited from the paternal side is the dominant antigen which is lacking in the maternal side. This antigen enters the maternal blood circulation through the placental villus, the corresponding antibody is produced after sensitization in the maternal body. This immunological antibody again goes through the placenta, enters the fetal blood circulation and integrates with the antigen of the fetal's red blood cells to produce a hemolysis reaction. Among the hemolytic diseases of new-borns in China, the most commonly seen is the ABO system, followed by the Rh system. The clinical expressions vary. In serious cases, general anssarca appear, dropsy of serous cavity, enlargement of the liver and spleen, anemia, and jaundice can also occur. The placenta itself has marked edema and enlargement.

Sonographic expressions:

(a) Mild fetal hemolytic disease
There are no obvious changes in the sonogram.
(b) Serious hemolytic disease
(i) The echoes of the entire skin and subcutaneous tissues of the fetus thicken, presenting double layers. If there is ascites, one may find the intestinal cavity floating in the ascites, or see the dark area of the hydrothorax.
(ii) The placenta thickens and enlarges, the echoes become weak.

Chapter 17

Ultrasonic Imaging Diagnosis of Gynecological Diseases

Ye Zhen

Clinical application of ultrasonic imaging diagnosis for gynecological diseases is becoming increasingly popular. The rate of accuracy for determining the existence, size, position and physical features of a tumor mass in the pelvic cavity can reach up to 90% approximately. The rate of accuracy in differenciating the cystic or solid nature of an ovarian cyst can reach beyond 95%. For cases unsuitable for gynecological examinations, and for cases where the patients are obese or have tense abdominal walls, B-mode ultrasound has its unique value, greatly compensating for the inadequecy of clinical examinations.

17.1. GENERAL DESCRIPTION OF THE ANATOMICAL PHYSIOLOGY OF THE INTRAGENITAL ORGANS OF FEMALES

The female intragenital organs consist of the vagina, uterus, fallopian tubes and ovaries. The latter two are often called the uterine appendages. The vagina is the passage to the intra- and extra-genital organs, the upper part is wide and the lower part is narrow. Its upper end embraces the uterine cervix, forming a vaginal formix. It may be divided into the anterior, posterior, left and right regions. The uterus is a vacuum organ, it lies in the centre of the bony pelvic cavity between the bladder and rectum, it has an inverted pear shape. An adult's uterus is 7–8 cm in length, 4–5 cm in width and 2–3 cm in thickness. The upper portion of uterus is wide — it is called the uterine body. The upper prominent portion is called the fundus of the uterus. The uterine cornu are at the two sides of the fundus, communicating with the fallopian tubes. The lower portion of the uterus is narrow, presenting a cylinder shape — it is called uterine cervix. The ratio of the uterine body to the uterine cervix is 1:2 in infants, 2:1 in adults, and about 1:1 in adolescents and the elderly. The uterine cavity is

triangular in shape, with a wide upper part and narrow lower part. The narrowest portion between the uterine body and uterine cervix is called the isthmus of the uterus. The internal cavity of the uterine cervix is shuttle-shaped. It is called the cervical canal and is 3 cm in length in an adult female. The wall of the uterine body is composed of three layers: the external layer is the serous membrane layer, namely the parietal layer of peritoneum, the middle layer is the muscular layer (in women who are not pregnant, it is about 0.8 cm in thickness), and the internal layer is the mucous membrane layer, namely the endometrium of the uterus. Beginning from adolescence, the endometrium undergoes periodical changes under the influence of the ovarian hormone.

The fallopian tubes lie on two sides of the uterine cornu, one on the left and one to the right side. They are a pair of slender, curved muscular canals with a total length of about 8–14 cm. From the internal orifice to the external orifice, the fallopian tube is divided into four parts: the interstitial portion, isthmus portion, ampullary portion, and infundibular portion.

The ovaries are a pair of flat, oval-shaped sexual glands located at two sides of the uterus inferior to the fallopian tubes and posterior to the broad ligament. The ovary of an adult female is about 4 by 3 by 1 cm^3. After menopause, the ovary shrinks and becomes hard. The ovarian tissues are divided into the external cortex layer and internal medullary layer. The cortex is composed of dense connective tissues containing follicles and lutein. The diameter of a matured follicle may reach approximately 20 mm. One ovulation occurs during each menstruation cycle (Fig. 17.1).

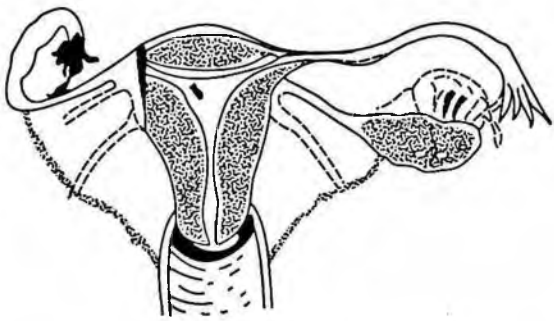

Fig. 17.1 Anatomy of the uterus and its appendage.

17.2. ULTRASONIC IMAGING EXAMINATION OF THE PELVIC CAVITY

17.2.1. Condition of the Apparatus

All types of B-mode ultrasonic apparatus can be used. The most commonly used frequency of the probe is 3.5 MHz.

17.2.2. Preparation Done by the Patient Before Examination

Avoid urination 2 hours prior to the examination. Drink 500 ml of water 30-60 minutes prior to the examination or pass urine in the morning of the examination, so that the bladder will have proper filling during the examination. Taking the bladder as the sonolucent window, the uterus and its appendages will be displayed clearly.

17.2.3. Body Position

Usually the supine position is assumed but the decubitus position can be used if necessary.

17.2.4. Procedure of Examination

In general, the method of direct examination through the abdominal wall is used. The probe is placed on the lower abdomen, at the upper margin of the pubis symphysis. First, scan in the longitudinal section to observe the position, form, and size of the uterus and its internal echo. Then scan in the transverse section to observe the relation in the positions of the uterus and the appendage. In the course of examination, scanning in multiple-directions and using multiple-angles is necessary. Sometimes, the tumor mass is small and deep-seated in the pelvic cavity, hence bimanual examination is used to hold up the mass for examination, or the examination is done after the needle probe is inserted into the uterine cavity in order to gain a better localization of the tumor mass.

17.3. THE ANALYTICAL METHOD OF ULTRASONIC IMAGING DIAGNOSIS OF GYNECOLOGICAL DISEASES

(a) Determine the position and size of uterus and appendage

(b) Judge the existence of the tumor mass
In general, a tumor mass has a clear outline and would not disappear with a change in the manipulation or direction of the section. But when the uterus is inclined too much, the uterine body and uterine cervix will separate, or when the uterus lies on the posterior position or is extremely deviated transversely, the uterine body and cervix will be present as two separate parts as well, which can be easily misdiagnosed as myoma or a tumor mass. In addition, an over-filled bladder, hard fecal mass, or kyrtorrachic can sometimes be mixed up. Hence, one should apply multiple-section scanning, examination by pressure, or examination on a symmetrical position in order to ascertain the existence of a tumor mass or lesion.

(c) Determine the origin of the mass (localization)
First, determine the position of the uterus to observe the relationship between the mass, or lesion, and the uterus. If a normal sonogram of the uterus disappears, one considers the mass to have originated from the uterus. In addition, observing the relationship between the mass and bladder before and after urination, changing the body position

or using manual pushing to determine the relationship between the mass and the nearby organs will help to localize the mass.

(d) Determine the physical nature of the tumor mass or lesion
   (i) Liquified tumor mass: the boundary of the mass is clear, the internal sonoluence is good, whether it is under normal sensitivity or raised sensitivity, the tumor mass presents echoless dark area.
   (ii) Solid tumor mass: under normal gain conditions, the internal part of the mass presents scattered, scarce echogenic dots. A solid mass with an even texture presents evenly-distributed echogenic dots. A solid mass with uneven texture presents echogenic dots of variable intensity, form and sizes, or mixed with a hyperechogenic mass.
   (iii) Mixed tumor mass: There are uneven reflections inside the tumor mass, both the liquified dark area and solid reflection area are present. Sonolucence is not identical in different parts of the tumor mass. It has the sonographic features of a cystic tumor mass and solid tumor mass.

(e) Determine the pathological nature of the tumor mass
Measure the size of the tumor mass, observe whether the boundary of the tumor mass is smooth or not, notice its regularity and outline morphology. By adding pressure or changing the body position, one can study the motility and tension of the tumor mass and if there is any tenderness. In general, in benign tumors, the outline is smooth, the morphology is regular, the boundary is clear cut, and the internal echo is even. For malignant tumors, the morphology is irregular, the surface is rough, the internal echo is disorderly, and it is usually accompanied by ascites. An inflammatory encapsulated mass is usually accompanied by tenderness.

(f) Combine clinical history
Combine gynecological ultrasonic examination with gynecological bimanual examination to determine the nature of the tumor mass in the pelvic cavity and give diagnostic opinions on the ultrasonic imaging.

(g) For certain undetermined cases, one may fix the time for re-examination or follow-up sessions in order to work out a correct diagnosis.

17.4. SONOGRAM AND NORMAL VALUES OF A NORMAL PELVIC CAVITY

In the longitudinal section, an oval-shaped uterus may be found posterior to the bladder, its outline is smooth, its internal echo is even in texture, it has a low-level echo area and its center may display somewhat strong linear or patch echoes of the endometrium. The position of the uterus varies with the individual. According to the relative positions of the long axis of the uterine body and the long axis of the uterine cervix, it may be divided into the anterior position, mid position and posterior position. In the transverse section, echoes of the round uterine body may be found posterior to the dark area of the bladder. Shift the position of examination to the posteroinferior and one may find the uterine cervix. The cervical canal presents a linear strong echo. In the transverse section, the position of uterus can be determined whether it is in a left-inclination or right-inclination (Fig. 17.2).

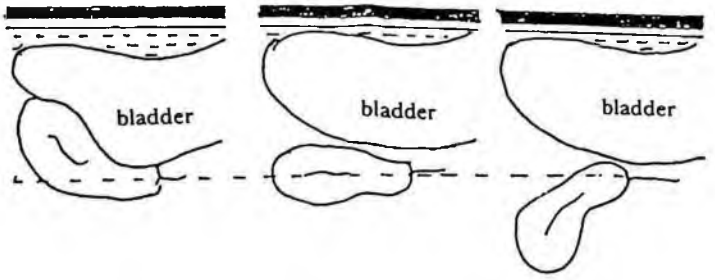

Fig. 17.2 Sketch map of the position of the uterus. Left figure: anterior position of the uterus; middle figure: middle position of the uterus; right figure: posterior position of the uterus.

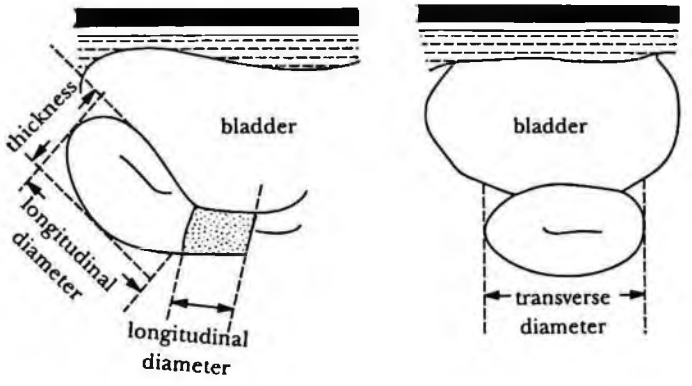

Fig. 17.3 Sketch map of the diameters of the uterus.

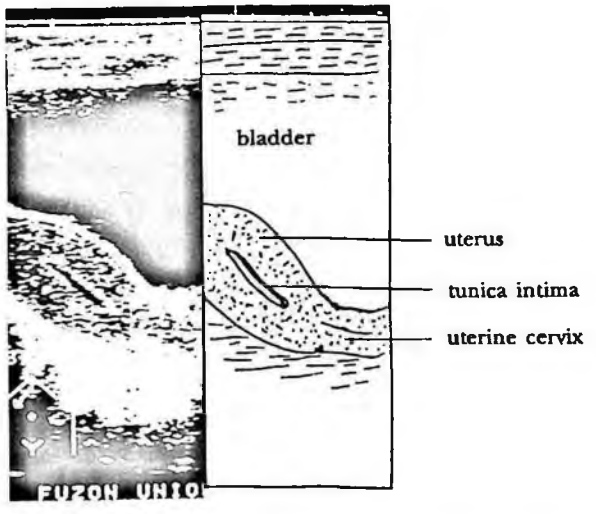

Fig. 17.4 Sonogram of each part of a normal uterus.

In the longitudinal section, one may sometimes find echoes of the upper segment of the vagina. Its mucous membrane also presents a light band with rather strong echoes.

The measurement of the volume of the uterus includes the longitudinal diameter, transverse diameter, and thickness (Figs. 17.3 and 17.4). The normal values of the diameters of the uterus in pluripara is bigger than those in nullipara, they become smaller again after menopause. The menstrual cycle does not effect the diameter much. For different positions of the uterus, the diameters have some differences, but in general, there is no difference in the longitudinal diameter. The thickness of the uterus at the posterior is greater than that in the anterior. Lu Enfan *et al.* from Beijing Gynecological Hospital did ultrasonic measurements on 558 cases of normal uterus. The results are shown in Table 17.1. In the past, in China, the values were considered normal when the total of the three diameters in a nullipara was not over 15 cm and not over 18 cm in the pluripara.

The fallopian tubes only display the beginning portion, presenting solid cord-like echoes. The widths are not greater than 8 mm (external diameter).

The ovaries in the transverse section are on a level which is a little higher than both sides of the uterine fundus near the lateral wall of the true bony pelvis, presenting a round or oval solid low-level echo area with even echoes. They are about 2.0–4.0 cm in length, 1.5–3.0 cm width, and 1.5–2.5 cm in thickness. In general, beginning from the 10th day of the menstrual cycle, one may find an echoless dark area of the developed follicle inside the ovary. Before ovulation, the diameter of the follicle may reach 1.6–2.6 cm. Sometimes, after ovulation one may find a thick-walled echoless dark area inside the ovary. The thick wall is lutein, which is being formed, and the fluid is the blood that has accumulated in the follicle. During ovulation, one may sometimes find small quantities of liquified echoes in the Dagnlas sac, which is derived from the follicular content, and the increment of secretion of fluid in the abdominal cavity. Also they are markedly increased in the early stage of lutein. The ovaries are often unclearly displayed due to improper filling of the bladder or flatulence in the intestine.

At both sides of the bladder, one may sometimes find echoes of the iliopsoas, presenting low-level echo masses similar to a pair of glasses.

Table 17.1 The Results of the Ultrasonic Measurements on 558 Cases of Normal Uterus

	Length (cm)	Width (cm)	Thickness (cm)	Cervix Length (cm)
Nullipara	5.07 ± 0.48	5.17 ± 0.45	3.56 ± 0.48	2.28 ± 0.34
Pluripara	5.73 ± 0.61	5.73 ± 0.53	4.25 ± 0.51	2.39 ± 0.41
With 2 years of menopause	5.14 ± 0.75	4.98 ± 0.56	3.59 ± 0.49	2.13 ± 0.37
Over 2 years of menopause	4.48 ± 0.62	4.41 ± 0.52	3.00 ± 0.52	1.95 ± 0.39

17.5. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE UTERUS

17.5.1. Adenomyopathy of the Uterus

17.5.1.1. *Clinic and Pathology*

Adenomyopathy is the benign invasion of uterine intima of the uterine muscular layer, accompanied by hyperplasia of the smooth muscles, often occuring in pluripara in women aged between 35–50 years. Before its onset, there is usually a short period of time when there is no pregnancy. The main clinical symptoms are an increase in menstrual flow or a prolonged menstrual period accompanied by a gradual increase in the severity of spasmotic abdominal pains during the menstrual cycle. The pathological changes of this disease may be divided into two groups:

(a) Diffusive type
The uterus undergoes even diffusive enlargement, but it is usually not greater than the size of a 3-month pregnancy. Sectionally, diffusive non-symmetrical increase in the thickness of the muscular wall is seen mostly in the posterior wall. The muscular bundle proliferates in the muscular layer, and one can find scattered, differently-sized small fluid cavities or small clefts between the muscular bundle.

(b) Localized type
The uterus presents irregular nodular shapes. One may find a small cyst accumulated with blood among them. About 6–15% of patients with this disease have endometriosis complications and 50% of them have uterine myoma complications. Occasionally, carcinogenesis occurs, forming adenocarcinoma of the endometrium in the muscular wall.

17.5.1.2. *Sonographic expression*

In diffusive type adenomyopathy, the uterus shows an even ball-like enlargement, but its thickness and width are not over 8–9 cm. If complicated with myoma, the uterus may enlarge markedly. The thickening of the muscular wall is obvious on the posterior wall. The intrauterine echogenic dots increase a little, become unevenly-distributed and disorderly without patterns. Sometimes, particularly during the menstrual period, one may find scattered small cysts with accumulated blood inside the uterus with a round, free-echo or low-level echo dark area. They are mostly distributed in the muscular layer, close to the serous membrane layer. In addition, the size of the uterus will change with the menstrual cycle. The uterus is bigger during premenstruation than during post-menstruation, and it is accompanied by mild tenderness. In the localized type, the uterus is irregularly enlarged or it may not enlarge at all. The local focus may have a ball-like body. If there is no bleeding, small dark area, it is difficult to differentiate it from uterine myoma. Besides, a chocolate cyst is often found in the pelvic cavity.

17.5.2. Metrypertrophia

17.5.2.1. *Clinic and Pathology*

Metrypertrophia refers to the even enlargement of the uterus. The thickness of the muscular layer is over 2.5 cm and it is accompanied by uterine hemorrhage. This is mostly seen in a multipara. The majority of the cases are accompanied by multiple follicular cysts in both of the ovaries. A minority of non-pregnant women may develop metrypertrophia from chronic myositis or stasis of blood in the pelvic cavity.

17.5.2.2. *Sonographic expression*

The uterus is evenly enlarged, the surface is smooth and the outline is clear. The uterine endometrium line is in the middle. Echoes of the uterine wall may be normal or may increase a little. The echoes are even and without nodular changes. The posterior wall of the uterus is displayed clearly. Sometimes, one may find multiple small, echoless dark areas in both ovaries of the patient.

17.5.3. Lieomyoma of the Uterus

17.5.3.1. *Clinic and Pathology*

It is a type of benign tumor most commonly seen in the female genital organ, mostly occuring in middle-aged women who are not pregnant. According to reports, 20% of women suffer from myoma. The main clinical symtoms are too much menstrual flow, a prolonged menstrual cycle or irregular vaginal hemorrhage with symptoms of oppression and masses. Gynecological examination shows an enlargement of the uterus. The uterus has a hard texture and a concaved or convexed surface. Myoma is derived from the muscular layer of the uterus or the smooth muscle tissues of the vascular wall at the muscular layer. It is mostly presented as a solid tumor and a pseudo capsule formed by loose connective tissues in its surrounding. When the tumor grows very fast, there is an insufficient supply of blood and ischemia will develop in the centre, causing edema, hyaline degeneration, red degeneration, cystic change, necrosis, calcification, and a series of degeneration. Above 90% of myoma is developed in the uterine body. According to its position and mode of development, it may be divided into three kinds: subserous membrane myoma (about 20%), intermuscular wall myoma (about 60–70%), and submucous membrane myoma (about 10%). Only approximately 0.5% of myoma develop in the isthmus of the uterus or in the uterine cervix. About 1% of myoma will undergo malignant changes.

17.5.3.2. *Sonographic expression*

(a) General sonographic changes of uterine myoma

(i) Enlargement of the uterus

A solid ball-like mass is seen inside the uterus. The uterus enlarges unevenly. Extraserous membrane myoma and multiple or big intermuscular myoma cause the

surface of the uterus to be uneven, convexed or concaved. Submucous membrane myoma and big intermuscular myoma often cause the intrauterine echoes to be curved and deformed (Figs. 17.5 and 17.6).

(ii) Echoes of myoma

The display varies with the size, number and position of the myoma. These may be expressed as solid masses with low-level echoes (mostly seen between the muscular wall or in multiple myoma) all are solid masses with strong echoes (mostly seen in submucous membrane myoma) or solid masses with uneven texture (mostly seen in multiple small myoma between the muscular wall (Fig. 17.5)).

(iii) Attenuation of echo posterior to the myoma

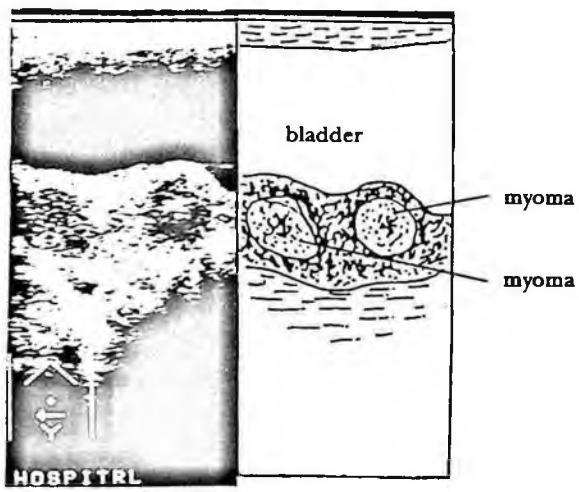

Fig. 17.5 Extraserous membrane myoma protruding into the bladder.

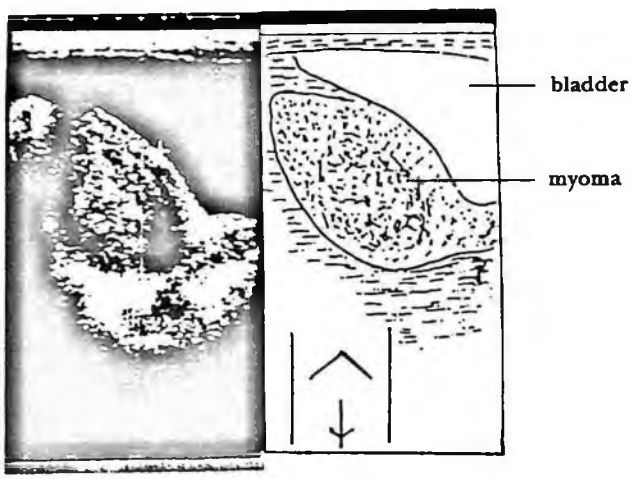

Fig. 17.6 Uterine myoma.

(b) Variation of the sonogram in degeneration of the myoma

(i) Hyaline degeneration: It is the most commonly seen type of degeneration. Hyaline degeneration occurs in the connective tissues of myoma. The sonogram displays an echoless dark area at the place of degeneration of the myoma, its sonolucence is good and an enhancement of the echo is seen at its posterior (Fig. 17.7).

(ii) Mucous degeneration and cystic degeneration: compared with hyaline degeneration, this is less commonly seen. Liquefaction of the tumor tissues form cavities of different sizes and is accumulated with mucous within. When it is further developed, a big cystic cavity is formed containing clear or bloody fluid. The sonographic expression is an echoless dark area with good sonolucence, enhancement of echoes at its posterior wall, and a clear boundary between the

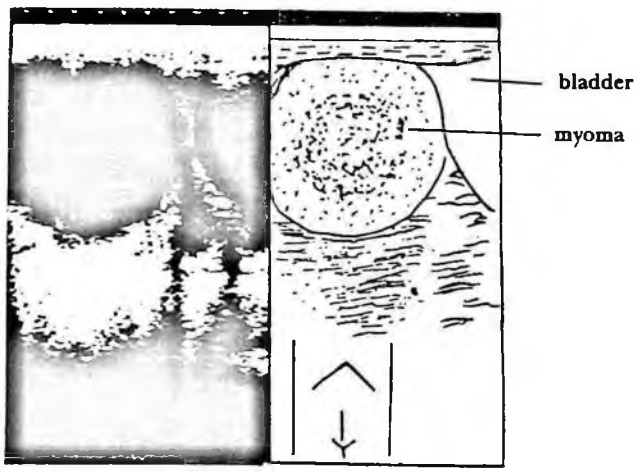

Fig. 17.7 Hyaline degeneration of uterine myoma, enhancement of the echo at its posterior.

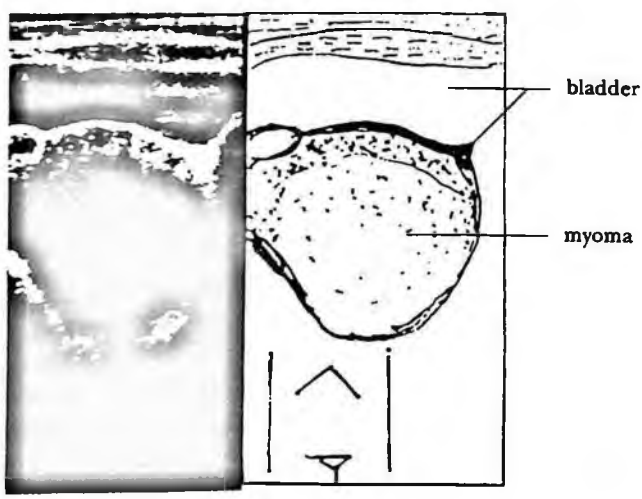

Fig. 17.8 Cystic change of the uterine myoma.

cystic cavity and the surrounding. If there is necrosis or incomplete liquefaction, scattered reflections of the echogenic dots can be seen in the echoless dark areas (Fig. 17.8).

(iii) Calcification: mainly seen in myoma chronically lacking in blood supply, causing deposition of calcium salt. It is often seen in women after menopause or in subserous membrane myoma with only a small pedicle. If the deposition of the calcium salt is scattered and scarce, it will appear sand-like; if the deposition of calcium salt is extensive, it will form a "uterine stone". The tumor is like a hard stone. The sonographic expression is of strong echoes at the calcified area, presenting a strong hyperechogenic mass of echo of light band. An acoustic shadow is seen at its posterior and the posterior wall of the uterus is not clearly displayed (Figs. 17.9 and 17.10).

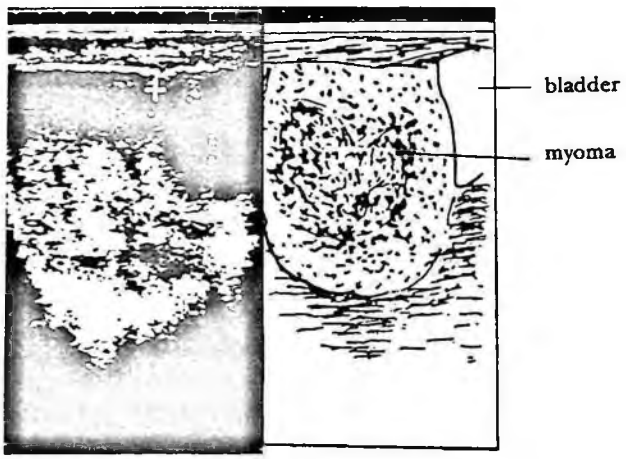

Fig. 17.9 Calcification of the uterine myoma.

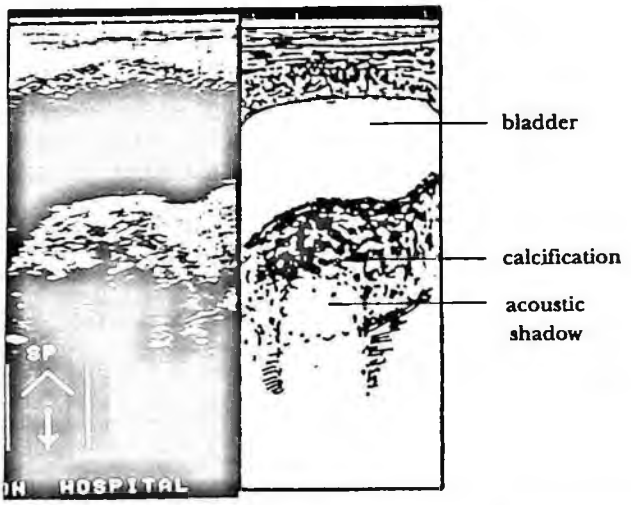

Fig. 17.10 Acoustic shadow seen posterior to the calcification of the uterine myoma.

(c) Gestation complicated with myoma

It is seen mostly in uterine intermuscular or subserous membrane myoma complicated with gestation. In early gestation, besides being able to examine the gestation sac in the uterus, the uterus is markedly enlarged, the surface is uneven, concaved or convexed, and echoes of myoma can be examined at the uterine wall. In gestation, the myoma is prone to enlargement and there is red degeneration of the myoma. The echo of the myoma also decreases (Fig. 17.11).

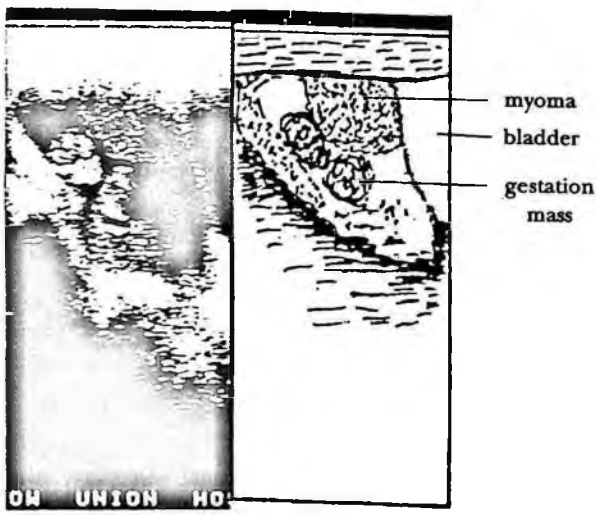

Fig. 17.11 Gestation complicated with uterine myoma.

17.5.4. Carcinoma of the Endometrium

17.5.4.1. *Clinic and Pathology*

The carcinoma of the endometrium is a commonly seen malignant tumor. The rate of incidence is about 6–9% of malignant tumors in the female genitalia, and is more than 90% of the malignant tumors in the uterine body. The main one is adenocarcinoma, often seen in menopausal women over 50 years of age. Most cases are complicated with hypertension, obesity and diabetes. The main clinical symptoms are irregular vaginal bleeding (women who have not reached menopause have prolonged menstruation periods or hemorrhage between the periods, while menopausal women have hemorrhage even after menopause) and discharge of watery or pus-filled secretion from the vagina. In the later stage, invasion of the carcinoma into the surrounding tissues of the endometrium or an abscess in the uteral cavity can cause lower abdominal pains. The pain may spread to the legs. Carcinoma of the endometrium often develops at the posterior wall of the uterus. In pathology, it may be divided into two types: (i) the diffusive type, whereby the majority or the entire endometrium of the uterine cavity shows polyoid or mushroom-like growth. The muscular layer or serous membrane may be involved, causing the uterine surface to present nodular prominence; and

(ii) localized type, whereby the tumor is localized at a certain part of the uterine cavity, presenting small polyoid or granular growth.

17.5.4.2. *Sonographic expression*

In early stages of the case, there may be no typical changes, thickening or enhancement of the hazy echoes of the endometrium line or disordered structure. In the mid stages, the uterine body becomes enlarged, smooth or nodular prominence may be found at the surface of the uterus. In the uterine cavity, solid masses of different sizes and of unequal strength of echoes can be found. They may have irregular forms and unclear boundaries and may protrude into the muscular wall. In the late stages, the uterus is markedly enlarged and irregular. Besides the internal echo expressions mentioned above, one may also find the tumor mass protruding out of the uterus, the echoes are disorderly and there is no clear demarcation with the surrounding tissues. Sometimes, one may find a dark area of fluid accumulating in the uterus. The key point for differenting carcinoma of the endometrium from myoma is the different echoes at the big interface. In addition, the possibility of carcinoma of the uterine body being complicated with uterine myocarcinoma should be considered in the diagnosis.

17.5.5. Sarcoma of the Uterus

17.5.5.1. *Clinic and Pathology*

Sarcoma of the uterus is a rarely seen tumor, occupying about 1% of the malignant tumors in the uterus of women between 40–60 years of age. It often develops in the uterine body, a develop few in the uterine cervix. Sarcoma of the uterus is derived from malignant changes of lieomyoma. Sarcoma is soft in texture and fish-flesh like on section. More than half of the cases are accompanied by necrosis and hemorrhage or cystic changes, and can infiltrate the surrounding muscular layer, even penetrating the serous membrane and spreading to the pelvic cavity. The main clinical expressions are irregular vaginal bleeding or a puriform, bloody, foul discharge, and rapid enlargement of abdominal mass accompanied by abdominal pains at the same time. If it metastizes to the lungs, one may have an irritative cough or even hemoptysis. Gynecological examinations reveal marked enlargement of the uterus, presenting many nodules, and a soft texture.

17.5.5.2. *Sonographic Expression*

The uterus is markedly enlarged, the surface is uneven, and there may be nodular prominence. The sarcoma presents a mass with low-level echo. If necrosis and hemorrhage develop, one may find enhancement of the echogenic dots or irregular echoless dark area. It should be differentiated from central necrosis and hemorrhage of a big myoma. Compared with sarcoma, myoma has a clear margin, regular outline, and the echo of the posterior wall is stronger than that of sarcoma. However, in the course of malignant changes, it is difficult to differentiate liemyoma from sarcoma by ultrasound.

17.5.6. Chorioepithelioma of the Uterus

17.5.6.1. *Clinic and Pathology*

Choriocarcinoma is a high-grade malignant tumor of the trophocyte that threatens the liver of young women. The majority are related to pregnancy, develop secondarily to a hydatid mole, miscarriage, or after a normal delivery. About 40–50% develop secondarily to hydatid moles. Its pathological feature is that the trophocyte loses its original villus or racemose tissue structure, undergoes scattered invasion of the muscular layer of the uterus, and far-distance metastasis. The uterus may experience irregular enlargement and the focus appears as a single or multiple purplish red nodule, with the diameter varying from 0.5 to 10 cm. It is located in the muscular layer of the uterus or may protrude into the surface of the serous membrane layer or the uterine cavity. The clinical expressions are irregular vaginal bleeding after development into hydatid mole, miscarriage or term birth. The HCG is raised, the uterus is enlarged, vascular pulsation may be found at the sides of the uterus and including the appearance of all metastatic focus and their respective symptoms.

17.5.6.2. *Sonographic Expression*

There is irregular enlargement of the uterus, one may find nodular prominence and its sonolucence is better than that of myoma. Irregular echogenic dots, hyperechogenic mass or a cord-like structure may be found in the uterine body. When the carcinomatous mass has hemorrhage and necrosis, different sizes of echoless small dark areas may be found in their respective positions. Some people consider the image feature of choriocarcinoma to be irregular, various sized multiple echoless areas. At both sides of the uterus, one may sometimes find the echoless dark area of the lutein cyst.

17.5.7. Endometritis of the Uterus

Acute endometritis is often found in patients suffering from an infection after child-birth or miscarriage. The patient experience lower abdominal pains accompanied by symptoms of a generalized infection, and lochia in the vagina increases. In general, chronic endometritis of the uterus has no symptoms. Serious cases may show irregular vaginal hemorrhage, affecting the menstrual cycle and the amount of flow. In acute endometritis of the uterus, the intima swells and show edema as well as congestion. In serious cases, there is pus exudating from the surface, thus it may involve the muscular layer and parauterine tissues. The sonographic expressions are enlargement of the uterus, increases in the width of the echo of the uterine intima, and enhancement and uneveness of the echo. In the intrauterine cavity, one may find an irregular small dark area, but the outline of the uterus is clear and the surface is smooth. The uterus lies in the middle and there is no attenuation at the posterior wall of the uterus. In chronic endometritis of the uterus, there is no marked specific alteration in the sonogram.

17.5.8. Retention of Fluid in the Uterine Cavity

This is often seen during adhesion of the cervix after an artificial labor or atresia of the hymen, causing retention of blood or pus due to acute infection. The clinical expression is

lower abdominal pains during the menstrual cycle. With infection one may have fever and an increase in number of white blood cells. The sonographic expressions are enlargement of the uterus, separation of the intima line in the uterine cavity, and the appearance of echoless dark areas. One may find the echo of echogenic dots where pus is retained. The size of the dark area varies with the amount of blood or pus retained. During atresia of the hymen, besides the retention of blood in the uterine cavity, an echoless dark area may also be found in the fallopian tube and vagina. Inside the dark area one may find patchy echoes. When applying pressure on the abdomen, the patchy echoes may float.

17.5.9. Perforation and Rupture of the Uterus

Perforation of the uterus is most commonly seen where there are mechanical injuries to the female genital tract. It is seen in artificial abortion, improper treatment of diagnostic curettage, during infiltration of a malignant tumor of the uterus to the uterine wall, in intestinal gestation and gestation in the rudimentary corna, and in the delivery of a difficult term using local methods causing perforation of the uterus. The clinical expressions are sudden attacks at the side or perforation or rupture. If a big blood vessel is involved in the perforation, internal hemorrhage will appear within a short period of time, followed immediately by shock. The sonographic expressions are: the outline of the uterus is interrupted at the site of perforation or rupture, there are localized prominence or sunken defects, and the ruptured uterine wall shows a little enhancement of the irregular echoes of the light band from the uterine cavity, intermittently extending to the site of defect at the uterine surface. At the site of defect of the uterine surface, solid echoes, slightly enhanced echoes, or disorderly echoes of blood clots can be detected. The form is irregular and the rectouterine excavation often has a dark area of retained fluid (Fig. 17.12).

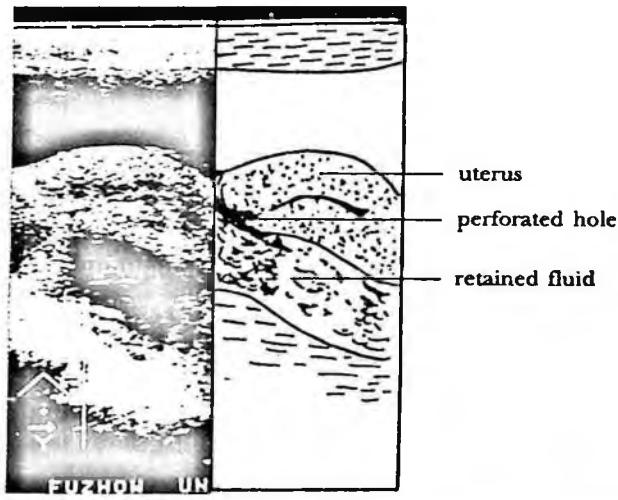

Fig. 17.12 Perforation of the uterus, rectouterine excavation retained with fluid.

17.5.10. Intrauterine Contraceptive Ring

The sonographic expression is a cord-like light band, a light circle of enhancement of intrauterine echo, accompanied by a light halo in the surrounding. The sonographic expression varies in different forms of plastic contraceptive ring, and its echo is lower than that of a metallic ring.

17.5.11. Malformation of the Uterus

17.5.11.1. *Clinic and Pathology*

Malformation of the uterus is the most commonly seen abnormal development in the genital organs. Abnormal development of the uterus can be divided into two groups: group one — incomplete development of the uterus, including congenital ametrian, rudimetary uterus, solid uterus and infantile uterus, and Group two — repeated, abnormal development of the uterus, including double uterus, uterus duplex, uterus bicornis, uterus unicornis and uterine septum. The clinical expressions are primary amenorrhea, scanty or excessive menstral flow, dysmenorrhea, and sterility.

17.5.11.2. *Sonographic Expression*

(a) Incomplete development of the uterus
No uterine image can be found during congenital ametria in the pelvic cavity. A rudimentary uterus or solid uterus expresses solid echoes of the uterus without intimal lines echoes inside. The former is very small, only 1–3 cm in length, the latter may be as big as or a bit smaller than a normal uterus. Infantile uterus expresses a small uterus in the sonogram, the cervix is relatively long, the ratio of the uterine body to the cervix is 1:1 or 2:3. The uterus often presents extreme anteflexion or retroversion.

(b) Repetitive abnormal development of the uterus
In the sonogram of a double uterus, one may find the two uterus placed on the left and right, or on the anterior and posterior. The uterine body is narrow and long. Tracing upwards, each uterus may have echoes at the beginning segment of one fallopian tube, and ovarian echoes. Tracing downwards, each cervix communicates with the respective vagina. In the longitudinal section, the uterus on the left and right sides lie on their respective sides of the lower abdomen. In the transverse section, the two uterine bodies may present butterfly, or dumbell-shaped echoes. There is a cleft in between. In a bicornis uterus, the fundus sinks and presents a double cornua due to incomplete union of the uterine fundus. In the sonogram, one may find a single vagina and single cervix. In the transverse section, at the level of the uterine fundus, the left and right side present cornual prominence, like a saddle. A unicornis uterus is the side with complete development of the paramesonephric duct, the echo is shuttle-shaped and it usually is deviated to one side. The other side of the uterus has incomplete development of the paramesonephric duct, or it is not perforated, forming the rudimentary cornu of the uterus. The uterine septum expresses a normal outlook of the uterus. A complete uterine septum will have septal solid cord-like echoes in the uterine body, which separates the uterus into two parts. Echoes of two intrauterine intimal line may be

detected. With an incomplete uterine septum, one can only examine the separation of the upper segment of the uterus and fusion of the lower segment into one body. In the transverse section, at the level of the uterine fundus, the uterine septum can be differentiated from the bicornis uterus.

17.6. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE OVARY

An ovarian tumor is also a common disease in gynecology. The average rate of incidence is 9% of the cases of gynecological diseases, the highest being is 23.9%. The age of onset begins from a fetus with an intrauterine gestation of 30 weeks to a female over 90 years of age. An ovarian tumor in the early stage usually shows no symptoms. When medical advice is sought, it is usually already in the late stage. Hence, the mortality is high. At present, there is a lack of specific methods of clinical diagnosis. B-mode is the best approach for diagnosing ovarian tumors. B-mode ultrasound examination can not only discover tumors, and determine its position and size, it can also carry out qualitative diagnosis.

17.6.1. Clinic and Pathology of An Ovarian Tumor

In general, ovarian tumors occur mostly on one side of the ovary, slightly more on the left side than the right. But malignant and certain benign tumors such as benign cysticteratoma, are often bilateral. Most identical tumors develop bilaterally in the late stage. The tumor usually retains the original form of the ovary, sometimes, it may be irregular. The volume of the tumors differ greatly, the smaller ones can only be detected under a microscope. The gross section of the tumor may be divided into cystic and solid. The former is sub-divided into single-loculated or multiple-loculated according to the number of cystic cavities. Solid tumors can be divided into complete or partial-solid.

Except in a minority of cases with hormonal functional expressions, in general, very few cases have specific symptoms. A big tumor may show oppression symptoms in the bladder and rectum. The common complications are as follows:

(a) Ascites
It is the complication of many malignant tumors, but sometimes it may be found in benign tumors such as "Marks sign" in fibroma — ascites complicated with unilateral hydrothorax.

(b) Twisting
The incidence rate is about 12–15%. It is mostly seen in tumors with a pedicle and without adhesion. The possibility of incidence is more in ovarian cystademmoma, fibroma and teratoma. The clinical expressions are acute abdominal pains, spasmotic or colic usually accompanied by vomiting, diahorrea, abdominal distension and constipation. During the physical examination, the abdominal muscles are tense, there is tenderness in the tumor and blood laboratory examination shows that the white cell count has increased.

(c) Ruputure of the the tumor
It is usually caused by twisting, hemorrhages, necrosis and infection. The clinical expressions and degree of expression may vary. Acute rupture may show signs of acute abdomen. In serious cases shock may also occur. This should be differentiated from ectopic pregnancy and acute appendicitis.

(d) Malignant change
A majority of the ovarian tumors are benign. Only about 1/4 of the tumors are malignant. In general, people consider most cystic tumors to be benign and most solid tumors to be malignant. Benign tumors may undergo malignant changes. For example, certain tumors are originally benign, but due to proliferation of the cell, they become malignant, such as the theca cell tumor. Certain tumors, such as the granular cell tumor and asexual cell tumor, have benign expressions clinically and pathologically. But after the operation, 1/3 of the cases may have a possibility of recurrence several years later, this is called clinical low grade malignancy. Certain benign tumors have a certain composition undergoing malignant changes.

17.6.2. Classification of An Ovarian Tumor

The pathological classification of the ovarian tumor is very complicated. There are many methods of clinical classification (Table 17.2). B-mode ultrasound classifies the tumors into the cystic and solid tumors in accordnace with their physical nature and pathological type. In accordance with certain image characteristics, the tumors are divided into benign and malignant tumors.

Sonogram of a cystic tumor: in general, the tumor presents a round or oval shape and is single-loculated or multiple-loculated, intralobular echoes may be liquified, echoless or flashing echogenic dots may be seen. The echoes of the posterior wall of the cyst are enhanced.

Sonogram of a solid tumor: in general, the tumor, is round or oval in shape and may be irregular. Solid echogenic dots are evenly or unevenly-distributed, with low level, equal or strong echoes. There are no enhancement effects at its posterior wall, but there is marked attenuation at the posterior wall of malignant tumors.

Features of the sonogram of a malignant tumor:

(a) The tumor mass is large, the majority of the cysts are multiple-loculated;
(b) Increase in thickness of cystic septum in cystic area, many solid areas appear;
(c) Irregular morphology, boundary not clear-cut, internal echoes are disorderly;
(d) Ascites are usually present.

17.6.3. Non–neoplastic Cyst and Hyperplastic Lesion of the Hyphen Ovary

17.6.3.1. *Follicular Cyst*

Due to immature development of the growing follicles or over-mature development, ovulation is unable to take place and the follicular cavity continues to be preserved. This kind of cyst is often seen and can occur at any age. The sonogram expresses a unilocular cyst on one side, it is round with a size not over 5 cm. The cystic wall is thin and smooth, and the

Table 17.2 Classification of Ovarian Cysts

1. Non-neoplastic cyst
   - 1.1. Physiological cyst
     - 1.1.1. Follicular cyst
     - 1.1.2. Theca cyst
       - (a) Atretic follicular cyst
       - (b) Lutein cyst
         - (bi) Theca-lutein cyst
         - (bii) Corpus luteum cyst
         - (biii) Corpus albicans cyst
       - (c) Polycystic ovaries
         - (ci) Polycystic ovary syndrome
         - (cii) Complications with trophozoite disease
   - 1.2. Ectopic cyst of the endometrium
   - 1.3. Inclusion cyst

2. Tumor derived from the germinative epithelium
   - 2.1. Serous
     - 2.1.1. Epitheiopapilloma
     - 2.1.2. Serous cystadenoma
       - (a) Benign
       - (b) Proliferating (borderline)
       - (c) Cystadenocarinoma
   - 2.2. Mucous
     - 2.2.1. Mucous cystadenoma
       - (a) Benign
       - (b) Proliferating (borderline)
       - (c) Cystadenocarcinoma
     - 2.2.2. Myxoma of the peritoneum
     - 2.2.3. Serous-mucous cystadenoma
   - 2.3. Endometroid tumor
     - 2.3.1. Endometroid cystadenoma (chocolate cyst)
     - 2.3.2. Proliferating
     - 2.3.3. Endometriod carcinoma
   - 2.4. Mesonephroid tumor
     - 2.4.1. Benign adenoma
     - 2.4.2. Moderately malignant
     - 2.4.3. Mesonephroid carcinoma
   - 2.5. Brenner tumor
   - 2.6. Adenoid tumor (mesodermal cell tumor)
   - 2.7. Other unclassified epitheal carcinoma

3. Tumor derived from the ovarian stroma
   - 3.1. Gonadal stroma tumor of the ovary
     - 3.1.1. Granular cell tumor

(Cont'd)

Table 17.2 (Cont'd)

- 3.1.2. Thecoma
- 3.1.3. Granulosa-theca cell mixed tumor
- 3.1.4. Arrhenoblastoma
- 3.1.5. Gynadroblastoma
- 3.1.6. Circular tubule gonadal stromal tumor
- 3.1.7. Sclerosing stromal
- 3.1.8. Lipoid cell tumor
  - (a) Adrenal-like tumor
  - (b) Hilus cell tumor
  - (c) Luteoma
    - (ci) Pregnancy luteoma
    - (cii) Stromal luteoma
- 3.1.9. Non-specific gonadal stromal tumor

3.2. Mesenchymoma of the ovary
- 3.2.1. Fibroma
- 3.2.2. Other benign mesenchymoma, including muscle, bone, fat, nerve and hemangioma
- 3.2.3. Sarcoma (including mixed mesenchymoma)

4. Tumor derived from the sexual cell

4.1. Derived from an undifferentiatred sexual cell
- 4.1.1. Dysgerminoma
  - (a) Simple
  - (b) Mixed

4.2. Extraembryonic cell tumor
- 4.2.1. Cherioepitheioma
- 4.2.2. Extraembryonic teratoma
- 4.2.3. Endodermal sinus tumor

4.3. Tumor derived from embryo sexual cell
- 4.3.1. Matured teratoma
  - (a) Benign cystic teratoma (dermoid cyst)
  - (b) Benign solid teratoma
  - (c) Benign teratoma malignant change
  - (d) Anapastic type of benign teratoma (simple teratoma)
    - (di) Thyroid tumor
    - (dii) Carcinoid
    - (diii) Myxoma
    - (div) Fetal-type teratoma
  - (e) Immatured teratoma, malignant teratoma

4.4. Extraembryonic and extraembryonic mixed tumor

4.5. Gonadoblastoma

5. Secondary ovarian tumor

5.1. Konkenberg's tumor

5.2. Others

boundary is clear. The echo at the posterior wall is markedly enhanced. This cyst has a tendency to disappear spontaneously and reappear alternately. It is sometimes hidden and sometimes seen in the examination, so it is called a fantastic tumor (Fig. 17.13).

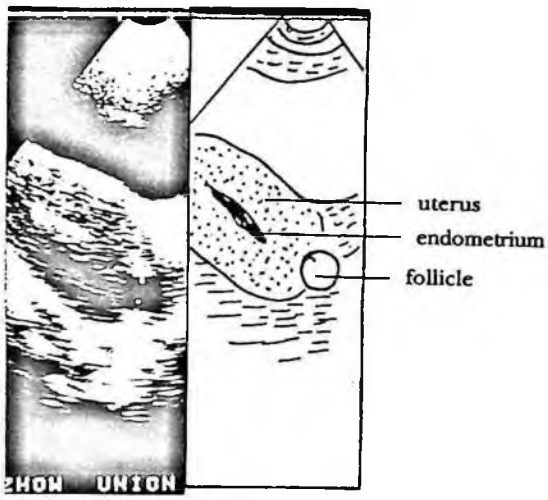

Fig. 17.13 Follicular cyst.

17.6.3.2. *Theca Cyst*

It is formed by the persistent existence and dilatation of the theca, it is mostly seen in early gestation. The sonogram displays a one-sided ovarian cyst, which may reach about 5 cm. It usually disappears spontaneously after 3 months of pregnancy.

17.6.3.3. *Lutein Cyst*

It is due to the stimulation of the follicle by chorionic gonadotropin when the trophozoite is diseased. In recent years, prolonged use, or the use of large amounts of drugs to induce ovulation, may cause the growth of the lutein cyst. The sonogram displays bilateral ovarian cysts with different sizes, the smaller one is about 3 cm and the bigger one may reach 10–15 cm. They possess typical ultrasonic images of cysts, and are mostly multiple-loculated. The cystic wall is very thin and will rupture with application of a slight pressure. After treatment of the hydatid mole or choriocarcinoma, the tumor mass will disappear spontaneously or be absorbed.

17.6.3.4. *Polycystic Ovary*

It refers to the ovary having multiple, small cysts. It is often accompanied by abnormal ovulation and other hormonal secretion. The cysts may be a growing follicular cyst or atreitic follicular cyst (with or without luteinization), or cysts of another nature, such as an inclusion cyst or ectopic cyst of the endometrium. Therefore, a polycystic ovary is a general concept

referring to multiple cysts in the ovary, it does not refer only to a solitary disease. The most commonly seen is the polycystic ovaries syndrome (S–L ovary). Most of the patients are young women who also have functional uterine hemorrhage, scanty menstruation, amenorrhea, sterility, are obese and hairy. The sonogram displays a bilateral enlargement of the ovary, 2–3 times the size of a normal ovary. The ovarian morphology is still normal with a thick capsule. Along the subcapsular region, one may find a circle nearly the same size as the echoless dark area. The diameter is about 0.2–0.5 cm.

17.6.3.5. *Endometriotic Cyst of the Ovary*

Due to an ectopic endometrium in the ovary and periodic hemorrhage retained in the ovary, a cyst is formed and it contains old blood, which is coaltar or chocolate-like, thus it is also called the chocolate cyst. After the cyst ruptures, the contents extravasate to form a rather strong adhesion with the surrounding tissues. The age of onset is usually between 30–40 years of age. The clinical expressions are mainly dysmenorrhea, sterility, abdominal pain, tenesmus and uterine hemorrhage. The sonographic expression is a thick-walled cyst at the fornix, posterior to the uterus. The wall may reach up to 1 cm thick. The boundary of the cyst is not clear, presenting a round or oval shape, and the size is over 10 cm in general.

Sonolucence is poor in the cystic dark area and one may find echoes of echogenic dots. The cyst is non-movable. About 40–50% of the patients have bilateral lesions.

17.6.4. Ovarian Cystic Neoplastic Tumor

17.6.4.1. *Benign Cystic Tumor*

(a) Serous cystadenoma

It is the most common ovarian tumor derived from the epithelium. It is a single-loculated or multiple-loculated cystic tumor. The covering epithelium is quite similar to the mucous epithelium of the fallopian tube, usually with papillary growth. It occurs in women between 30–40 years of age. According to the different modes of growth, it may be divided into single-loculated serous cystadenoma and serous papilliary cystadenoma.

(i) Single-loculated serous cystadenoma: the tumor is a single-loculated, thin-walled cyst, and it is very rarely bilateral (2.2%). Sectionally, one may find a ball-like single-loculated cyst in the appendageal area. The size may be just several millimeters bigger than a child's head. The wall is smooth and the sonolucence is good in the dark area. There is an enhancement of the echoes posterior to the tumor (Figs. 17.14 and 17.15).

(ii) Serous papillary cystadenoma: it is characterised by cystadenoma accompanied by papillary growth. About 15% are bilateral, the size varies, and the diameter is 3–30 cm in general. Sectionally, they are round, multi-loculated cystic tumors, the loculus can be of different sizes, and in the internal wall, one may find papillary solid echo, with a rather big base, protruding into the cystic cavity. Within the papilla, 30% are minute echogenic dots with a strong echo, accompanied by acoustic shadows at the posterior. Sonolucence is good in the dark area inside the cystic cavity (Figs. 17.16 and 17.17).

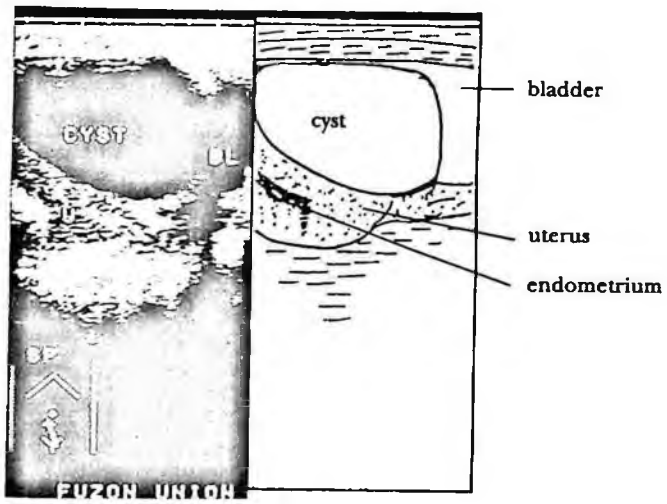

Fig. 17.14 Ovarian cyst displaces the uterus posteriorly, should be differentiated from the bladder.

Fig. 17.15 Gigantic ovarian, single-loculated serous cystadenoma.

(b) Mucous cystadenoma

Most tumors are unilateral (90%), the average size is 15 cm. The bigger ones may reach the size of term pregnancy. The tumor is oval or round in shape, the surface is smooth or presents a shallow big lobulation. In the cross-section, one may find multiloculation, the internal wall is smooth. One may find papillary structure or solid thickening of the cystic wall. 5% of the tumor is mixed with teratoma, 5–10% of the tumor may undergo malignant changes.

Sonographic expressions: in the parauterine appendageal area, one may detect poly-loculated cysts, a small number (6.8%) of them may be single loculated cysts. The loculus varies greatly, the distribution of the loculus may be scarce or dense, and it is very often within a loculus that there is encapsulation of one or some smaller daughter

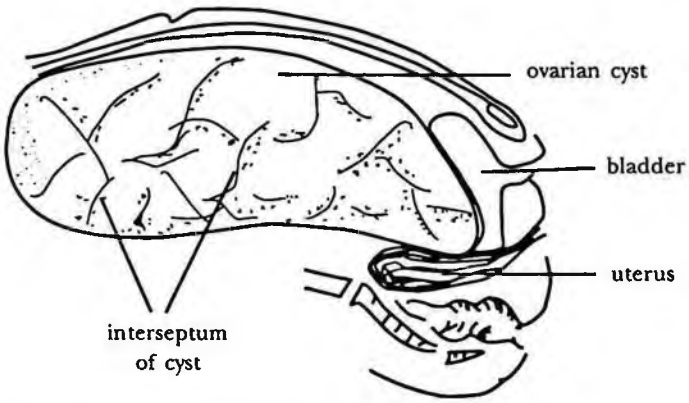

Fig. 17.16 Sketch map of a ovarian poly-loculated serous cystadenoma.

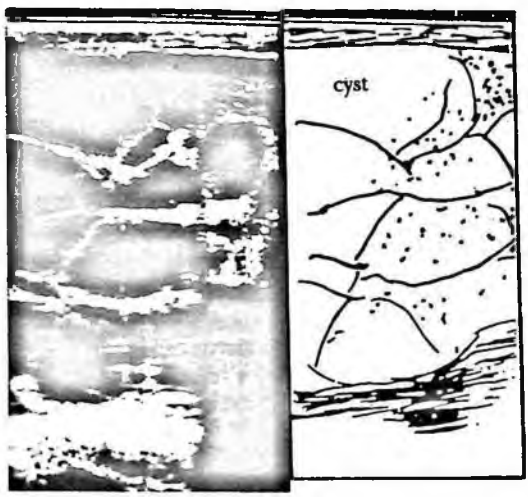

Fig. 17.17 Ovarian poly-loculated serous cyst.

loculus. A daughter loculus is a special sonogram of this disease. In dense concentrated areas of the loculus, a false solid area is detected. Careful examination may show numerous honey comb-like small loculi concentrated together. Inside the cystic cavity, one can find scattered echogenic dots. Echoes posterior to the cystic wall may be enhanced (Fig. 17.18).

(c) Benign cystic teratoma

It is one of the most commonly seen ovarian tumors. The rate of incidence is about 10% of that of the ovarian benign tumor. It may occur at any age, but the age of incidence differs greatly. A commonly seen ovarian tumor in a small girl occupies about 25%. The volume of the tumor is small. In general, it is limited within 5–10 cm, and it is seldom over 15 cm. The tumors are mostly unilateral, 10–17% are bilateral. Cross-sectionally, most tumors are single-loculated or poly-sloculated. The thickness of the intracystic wall is uneven, granular or nodular prominence may be found. The cyst is fully-filled with sebaceous and other different contents, such as hair, tooth, and bone.

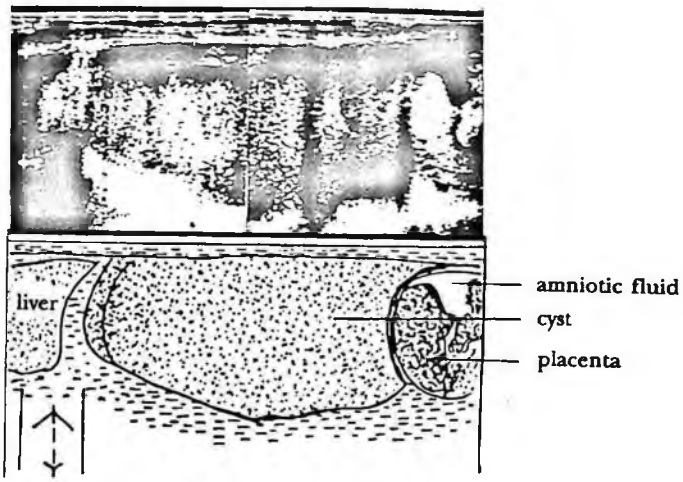

Fig. 17.18 Giant ovarian mucous cystadenoma.

Sonographic expression: since the tumor tissues are derived from three different embryonic layers, the sonographic expression also has multiforms. Cystic teratoma is usually seen anterior to the uterus, it is mostly uniloculated, and the outline of the tumor is not as clear as that of a simple cyst. Generally, the internal echoes may be divided into cystic tumor, solid-like tumor, and mixed-type tumor.

(i) The cystic-like tumor is similar to a simple cyst. The cystic wall is thin and smooth. The upper portion of the intracystic echo has enhancement of evenly minute echogenic dots, while the lower portion is a bright echoless area. Between these two is a distinct fluid interface which will change with a change in the body position. But the relationship between the echoes of the above-mentioned two layers is unchanged. This sign is also called the "fluid–fluid level with floating material sign". Sometimes, a linear septum, similar to a poly-loculated cyst, may be found inside the cyst.

(ii) The solid-like tumor has a clear and smooth boundary and a thick cystic wall. Within the cyst, one may find a hyperechogenic mass attached to the wall of the cyst, mount-like nodules, or arc-like and strip-like echoes, and it may be accompanied by acoustic shadows at the posterior. Pathologically, one mostly sees a bundle of bush-like hair and all embryonic layer tissues, such as a tooth, finger bone, cartilage, and possibly the thyroid tissues and mucous membrane of the gastrointestinal tract, but the vertebral bone is absent (Fig. 17.19).

(iii) The mixed-type possesses the features of the echoes of both types mentioned above.

17.6.4.2. *Malignant cystic tumor*

(a) Serous cystadenoma

It is the most commonly seen primary malignant tumor of the ovary, occupying 50% of the malignant tumors of the ovary. It occurs mostly in people between 40–60 years of

Fig. 17.19 Ovarian teratoma.

age, the bilateral ones occupy 50–60%. The tumor is usually medium in size but a small number of them may be extremely big. Sectionally, it is poly-loculated, it may have a patch of papillary or solid area. The rate of incidence of the papilla invading the capsule and spontaneous perforation is very high. Ascites and signs of infiltration to the abdominal cavity appear early, the tumor grows rapidly, and there is often insufficient supply of blood, causing tissue ischemia and necrosis. The fluid inside the tumor may become turbid due to hemorrhage and necrosis.

Sonographic expression: 50% of the tumors are bilateral, the size of the tumor is medium, more than half of the cases have a size more than 15 cm. The sonogram of the tumor often shows an irregular poly-loculated cystic cavity. Inside the cystic cavity are scattered, bloody, turbid, floating echogenic dots. There are many papillary prominence on the cystic wall, 2/3 of the cases present semi-solidity, the cystic wall is rough and uneven. In the late stage, one may find signs of metastasis to the surrounding viscera, signs of metastasis to the liver, and far distance metastasis may also be detected (Figs. 17.20 and 17.21).

(b) Mucous cystadenocarcinoma

The rate of incidence of mucous cystadenocarcinoma is lower than that of serous cystadenocarcinoma. Usually unilateral, the average age of occurrence is 44 years of age, the oldest being 74 years of age. The most common symptom is abdominal pains or abdominal distension. 17% of the patients also have irregular vaginal bleeding or irregular menstrual flow, while others have no symptoms at all. The tumor is usually round or oval, the majority of them are poly-loculated, solid or partially-cystic, but exophytic papilla is rare. Sectionally many loculi are seen, the loculi are many and concentrated. The solid area and hard nodular area are distinctive, sometimes they occupy the majority of or the entire tumor. Hemorrhage and necrosis of the tumor cause the mucous fluid inside the cyst to become turbid or bloody. The incidence rate of the spontaneous rupture of the capsule is 20.68%, usually adhering to the omentum major and the nearby tissues.

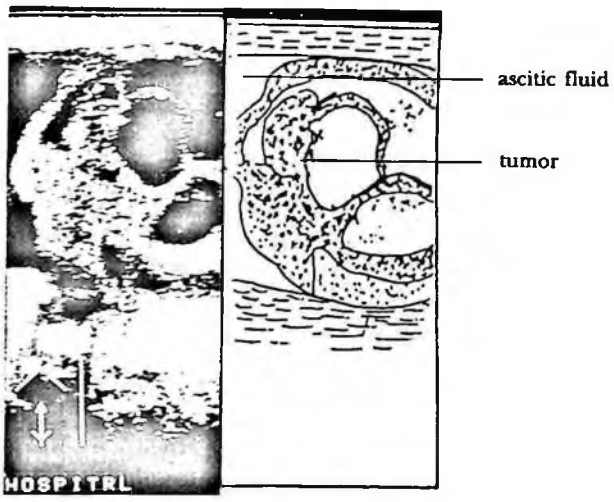

Fig. 17.20 Ovarian cystadenocarcinoma.

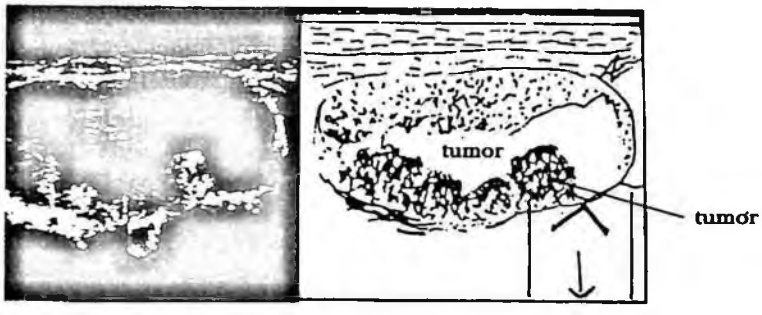

Fig. 17.21 Papillary prominence of the cystic wall in ovarian cystadenocarcinoma.

Sonographic expression: it is mostly seen on the right side, 15% of them are bilateral. The size of the tumor varies. The section is irregular and poly-loculated. The cystic cavities are many and concentrated. The interface between the dark area is unclear. The light band of the intercystic septum is irregularly-thickened. One may find an increase in the solid portion, and in certain cases it may occupy the entire tumor. Due to the hemorrhage and necrosis of the carcinomatous tissues, there are many echogenic dots and irregular hyperechogenic masses in the dark area of the cystic cavity. In the late stage, a metastatic focus of the carcinoma tumor may appear.

17.6.5. Ovarian Solid Tumor

Most of the solid tumors of the ovary are derived from the mesodermal tissue cells. The majority are malignant, only 15% of them are benign.

17.6.5.1. *Benign Solid Tumor*

The commonly seen ones are fibroma, lieomyoma, fibroepithelioma and angioma. In general, there are no typical symptoms except for tumors in the abdominal mass. The sonographic expressions are:

(a) Normal uterus size;
(b) Most tumors and unilateral;
(c) Fundamentally, the original morphology of the ovary is retained. The surface is smooth, outline is clear and the posterior wall is without any distinct attenuation;
(d) The internal echoes of the tumor present evenly-scattered minute echogenic dots, sometimes accompanied by small echoless areas;
(e) Fibroma and the Brenner tumor may be accompanied by ascites and unilateral hydrothorax, this is called "Mark's sign".

17.6.5.2. *Malignant Solid Tumor*

The commonly seen ones are ovarian adenocarcinoma, embryonic carcinoma, sarcoma and chorioeptheliocarcinoma. The sonographic expression: in general, the tumor is rather big, it has an irregular morphology, its outline is not clear, and its margin is irregular. The tumor does not have echoes of the capsule, the strength of the internal echoes are uneven and disorderly. Both echogenic dots and a hyperechogenic mass may be found. When accompanied by hemorrhage and necrotic degeneration irregular liquified echoless dark areas may be found. Attenuation is marked at the posterior of the tumor. In the late stage, one often finds a metastatic focus of the tumor and signs of ascites.

17.6.6. Ovarian Metastic Tumor

The incidence rate of the metastatic tumor of the ovary is about 15–60% of all malignant tumors, which is close to the incidence rate of primary tumors. Certain organs in the human body have a high tendency of metastatisizing to the ovary, for example, the incidence rate of Krukenburg's tumor, i.e. carcinoma of the stomach, metastatizing to the ovary is about 80%. About 25–40% of primary carcinoma of the breast undergo metastasis to the ovary. Malignant lymphoma, particularly Burkitt lymphoma, also metastases easily to the ovary. These metastatic tumors may reveal their clinical symptoms before the primary focus and hide the presentation of the primary focus, therefore during examinations one must search thoroughly for the primary focus. The age of onset of metastatic tumors of the ovary is lower than than that of primary carcinoma of the ovary. The former is approximately between 40–50 years of age. Clinically, in most cases, medical advice is sought due to the abdominal mass. Some may be the accompanied by symptoms of feminization or disturbance of the ovarian functions causing amenorrhea. The patient usually has symptoms of discomfort of the primary focus, such as symptoms of the digestive tract and anemia. In the late stage, there are usually marked ascites and signs of cachexia.

Sonographic expression: Krukenburg's tumor develops bilaterally. In the early stage, it is completely solid, usually as big as a fist. Its echoes are slightly stronger and coarser than those of the liver, they are unevenly distributed and have smooth surfaces. Along with the growth

of the tumor, necrosis and hemorrhage may occur. The tumors may show a mixed display of solid tumors and cystic tumors. The number of liquified dark areas contained in the tumor body is not equal, may be single or multiple, but all are single-loculated. The patient usually has dark areas of ascites and hydrothorax also. Both the metastatic focus to the ovary and the metastatic focus to the liver from the mucous cell carcinoma present identical "bull's eye sign". Within an enlarged ovary, one may find many foci: the center of the focus has mass echoes, surrounding it is the dark area; most of the metastatic tumors from carcinoma of the breast have mass echoes; the metastatic tumors from the malignant lymphoma often have low-level to equal echo masses, they may reach 7–8 cm, have smooth surfaces and the echos are still even. When necrosis and hemorrhage occur, the local echo is lower than the echo of the mass, or echoless small dark areas are presented (Fig. 17.22).

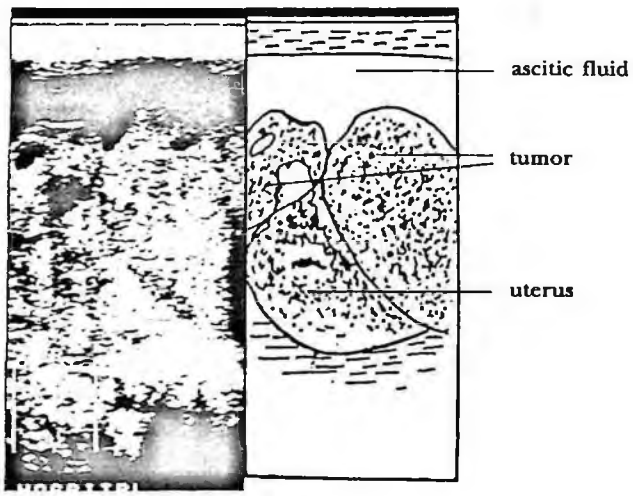

Fig. 17.22 Metastatic tumor of the ovary.

17.7. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE FALLOPIAN TUBE

The majority of the diseases of the fallopian tube are related to inflammation and the after-effects of inflammation, for example, acute and chronic salpingitis, hydrosalpinx, and pyosalpinx. The clinical expressions are dysminorrhea, irregular uterine bleeding and lumbago. The incidence rate of tumor of the fallopian tube is not high, it is in fact most rarely seen in gynecology. Most of them are malignant tumors. Benign tumors are far less common.

17.7.1. Acute Salpingitis

Acute salpingitis is one of the common diseases in gynecology. It is usually due to improper treatment of abortion or child birth, or it may occur after contracting with veneral diseases. Clinically, the course is short, and in the majority of the cases it becomes chronic

inflammation. The clinical expressions are acute abdominal pains, increased leukorrhea, high fever, vomitting and abnormal menstruation.

Sonographic expression: echoes of the fallopian tube drop, there is an increase in the tubular calibre, the external diameter of the interstitial and isthmus portion is bigger than 1 cm, presenting areas with round, oval or irregular low-level echoes. Scarce echogenic dots may be found inside, the margin is hazy and unclear, and the surrounding has an accumulation of dense, strong echogenic dots.

17.7.2. Chronic Salpingitis

The majority of the cases are carried down from acute inflammation or the after-effects of improper treatment. The patient may suffer from sore pains in the lumbar region, secondary dysmenorrea, menorrhagia, sterility or ectopic pregnancy. According to pathological changes, it may be divided into chronic interstital salpingitis, pyosalpinx, hydrosalpinx, and tubo-ovarian mass.

Sonographic expressions:

(a) Chronic interstitial salpingitis
There are no abnormalities in the sonogram, it is not easily diagnosed;

(b) Abscess of the fallopian tube
This is due to atresia of the orifice of the fallopian tube and partial or complete obstruction of the tubal cavity causing retention of pus. If the fimbrial end of the fallopian tube is tightly adherent to the ovary, a rather big abscess is formed between these two, which is called the ovarian tubal abscess. Sonographic expression: unilateral or bilateral fallopian tube presents a round, oval or irregular shuttle-like echoless area. Inside it, one may find scattered echogenic dots, light patches, hazy and unclear boundary, as well as enhancement of echoes at the posterior wall. In the surrounding,

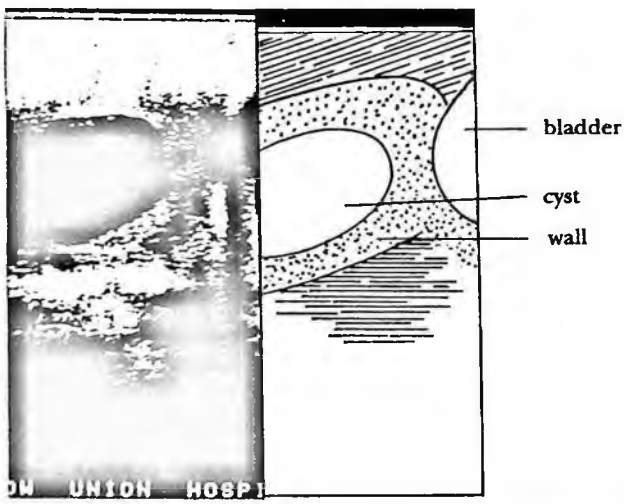

Fig. 17.23 Twisting of the pedicle of an ovarian cyst, edema and thickening of the cystic wall.

one may also find gasesous strong echoes by the adherent intestinal echoes. This should be differentiated from the twisting of the pedicle of an ovarian cyst (Fig. 17.23);

(c) Hydrosalpinx

The majority is the result of an abscess of the fallopian tube. The pus cell in the abscess is dissolved and absorbed, leaving behind a clear fluid which forms hydrosalpinx. The sonographic expression shows the unilateral or bilateral fallopian tube presenting a sausage-like, oval or retort-like echoless area, with a thin wall. The internal sonolucence is still good, there are enhancement effects at the posterior wall and the size is less than 15 cm. However, there are reports of giant hydrosalpinx reaching a volume of $(39 \times 30 \times 19)\ cm^3$.

17.7.3. Tumor of the Fallopian Tube

Benign tumors are very rare, these include lieomyoma, fibroma, adenofibroma and teratoma. In malignant tumors of the fallopian tube, adenocarcinoma is most commonly seen, the others like sarcoma, choriocarcinoma and mixed tumor of the mesoderm are only seen occasionally. The incidence rate of carcinoma of the fallopian tube is 0.16–0.5% of all tumors of the female genital organ, and it mostly occurs between 40–60 years of age. About half of the patients have a history of sterility, and in most patients the most typical symptom is vaginal discharge. About 60–80% of the patients have vaginal discharge. When vaginal discharge fluid is accompanied by an abdominal mass, it is called the bigeminal symptom.

Sonographic expression: there is no distinct boundary between the fallopian tumor and uterus, the tumor is mostly located obliquely superior to the uterus, and its position is rather superficial. The outlook of the tumor is mostly sausage or retort-like. The fallopian carcinoma usually develops on one side, the tumor is solid and its margin is irregular, presenting a cauliflower-like mass. The echoes are uneven, 50% of the patients may also have a hydrosalphinx dark area due to occlusion of the fimbrial end.

17.8. ABSCESS IN THE PELVIC CAVITY

Benign inflammation of the pelvic cavity extends to the pelvic peritoneum, inducing congestion, edema and exudation of the peritoneum, hence causing adhesion between the pelvic organs. In serious cases, there may be large amounts of exudated pus accumulating to form an abscess in the pelvic cavity. It is usually located in the rectouterine excavation. The clinical expressions are fever and low abdominal pains. Gynecological examinations may detect limitations to the motility of the uterus. A mass may be felt at the posterior fornix or lateral fornix, with sensations of wave motion.

Sonographic expression: Posterior or lateral to the uterus one may find an irregular echoless area whose boundary is unclear. Sonolucence of the internal echoes is poor, and one may also find scattered echogenic dots or light patches. If extensive adhesion of the pelvic organs develop, the internal echoes become disorderly. It is hard to differentiate that from old ectopic pregnancy. A detailed understanding of history is of great significance for differential diagnosis (Figs. 17.24 and 17.25).

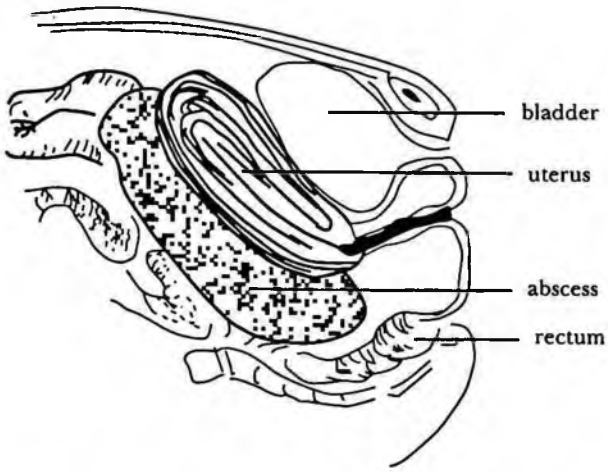

Fig. 17.24 Sketch map of the abscess in the pelvic cavity.

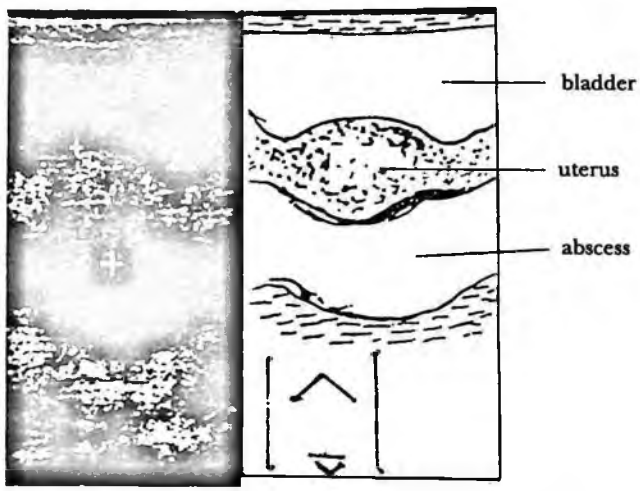

Fig. 17.25 Abscess in the pelvic cavity.

17.9. B-MODE ULTRASOUND MONITORING METHOD OF UTEROTUBAL PASSING FLUID

B-mode ultrasound monitoring method of uterotubal passing fluid is not only an examination method used to determine whether the fallopian tube is patent, but it is also used to assist in the clinical diagnosis of lesions of the uterus, fallopian tube and ovary.

Method: the patient is examined 3–7 days after the menstruation has been fully discharged. The bladder is moderately-filled and the patient is in the supine position with the buttocks raised (about 30°). At the lower abdomen, first make a routine examination of the uterus and appendages by B-mode ultrasound and take down the records. Then operate tubal

passing fluid as routine. First, instill 5–10 ml of normal saline through the uterine cervix to separate the uterine cavity. At this moment one may find a liquified dark area in the uterine cavity and echoes of small amounts of tiny bubbles. Then slowly instill 10–20 ml of 2.5–3.0% H_2O_2, and observe carefully whether there is small-bubble-strong-echo-peristalsis in both of the tubal cavities. During the passing of fluid, there are echoes of strong bubbles in the uterus, and both tubal cavities serve as a foil to the uterus, ovary and fallopian tube. If there is a lesion, it will be displayed more clearly at this moment. If gentamicin is used for passing fluid, one will find two linear dark areas appearing in the fallopian tubal cavity from both sides of the uterine body, gradually extending outwards.

Diagnosis: if the fallopian tube is patent, strong echoes of the bubble from the fallopian tubal cavity will undergo peristalsis and escape to the fimbrial end of the tube during passing fluid. If the fallopian tube is obstructed, strong echoes of the small bubbles at the obstructed side of the tubal cavity at the end of the uterus undergo peristalsis but do not escape. Sometimes, one may find the tubal cavity dilated in this segment, or the patient may feel lower abdominal pains with distention. If obstruction occurs on both sides, the fluid will flow back to the vagina from the uterus.

Part 4

Ultrasonic Imaging Diagnosis of Cardiothoracic Diseases

Chapter 18

Ultrasonic Clinical Diagnosis of Angiocardiopathy

Fang Jialiang, Lin Liwu

Contemporary ultrasonic diagnosis can use all modes to reflect the structure of the cardiovascular anatomy. It can also be used to acquire information regarding certain functional conditions, thus fulfilling the purpose of having a non-traumatic diagnosis of angiocardiopathy. Nowadays, M-mode ultrasound cardiogram and section (two dimensional) ultrasound cardiogram are widely used in clinics. Doppler ultrasound cardiogram further increases the ability of the diagnosis of angiocardiopathy by ultrasound. Recently, the study and application of qualitive diagnosis has advanced to include quantitative diagnosis. Combined with the application of ultrasound cardiogram, it is very valuable in diagnosing valvular regurgitation and intracardiac shunt. It can also estimate the velocity and characteristic of blood flow at different positions inside the heart, and evaluate the area of the valve orifice as well as transvalvular pressure difference.

In recent years, real-time two-dimensional color Doppler flow imaging has been applied in clinics. This technique has a high sensitivity and specializes in the diagnosis of small shunts and regurgitation, multiple lesions, and abnormal blood flow. Ultrasonic contract examination plays an important role in diagnosis of congenital angiocardiopathy. Recently, left heart radiography and myocardial perfusion imaging are under discussion. Performing puncture drainage under the guidance of ultrasound and the technique of biopsy of the myocardium are also gradually being applied clinically. Due to limitation of the pages in this book, we can only make a brief introduction to ultrasonic diagnostic techniques such as M-mode, B-mode and Doppler ultrasound on common angiocardiopathy, and attach many typical pictures for comparison and reference.

18.1. M-MODE ECHOCARDIOGRAPHY

18.1.1. Fundamental Principles

M-mode ultrasound cardiogram displays echogenic dots on the oscillagrams. Based on the different density of each heart tissue structure, the strength of the echogenic dots of ultrasonic reflection varies depending on the different distance from the physical surface. The vertical direction represents the depth of the heart structure to be examined, the horizontal direction represents the time. Along with the periodic movements of the structure of every layer of the heart tissue, the ultrasound beam meets the tissues of a certain part of the heart, producing a "distance–time" diagram of curves of echo motion. This is the M-mode ultrasound cardiogram (Fig. 18.1). Clinically, it is used to observe the interface motion curve of the structure of each heart layer and the cardiac cycle. In the electric circuit, the electrocardiogram, cardiophonogram and apexocardiogram are attached with an ultrasound cardiogram to make the graph synchronous.

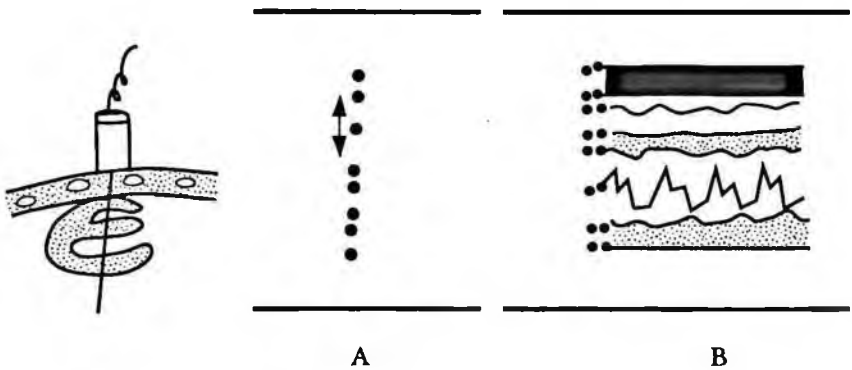

Fig. 18.1 Sketch map of the working principle of an M-mode echo cardiography: (A) Sonogram of B-mode apparatus, echogenic dots of the heartbeat move up and down only; (B) After serrated wave is slowly detected by x-axis, the group of echogenic dots will spread from left to right with a definite speed, forming a continuous scanning curve.

18.1.2. Important Points of M-mode echocardiography Examination and the Normal Diagram

Ultrasound cardiogram diagnosis is closely related to skillful examination methods. First of all, one must modulate the apparatus well to make the echogenic dots bright and well-focused, paying attention to the modulation of the near-field and far-field gain. Any position on the physical surface which can allow the ultrasound beam to pass through to the heart can be used as an examination position. The three commonly used positions are the precardial region, suprasternal fossa, and infraxyphoid position. Among them, the precardial region is the most common region used for examination (Fig. 18.2).

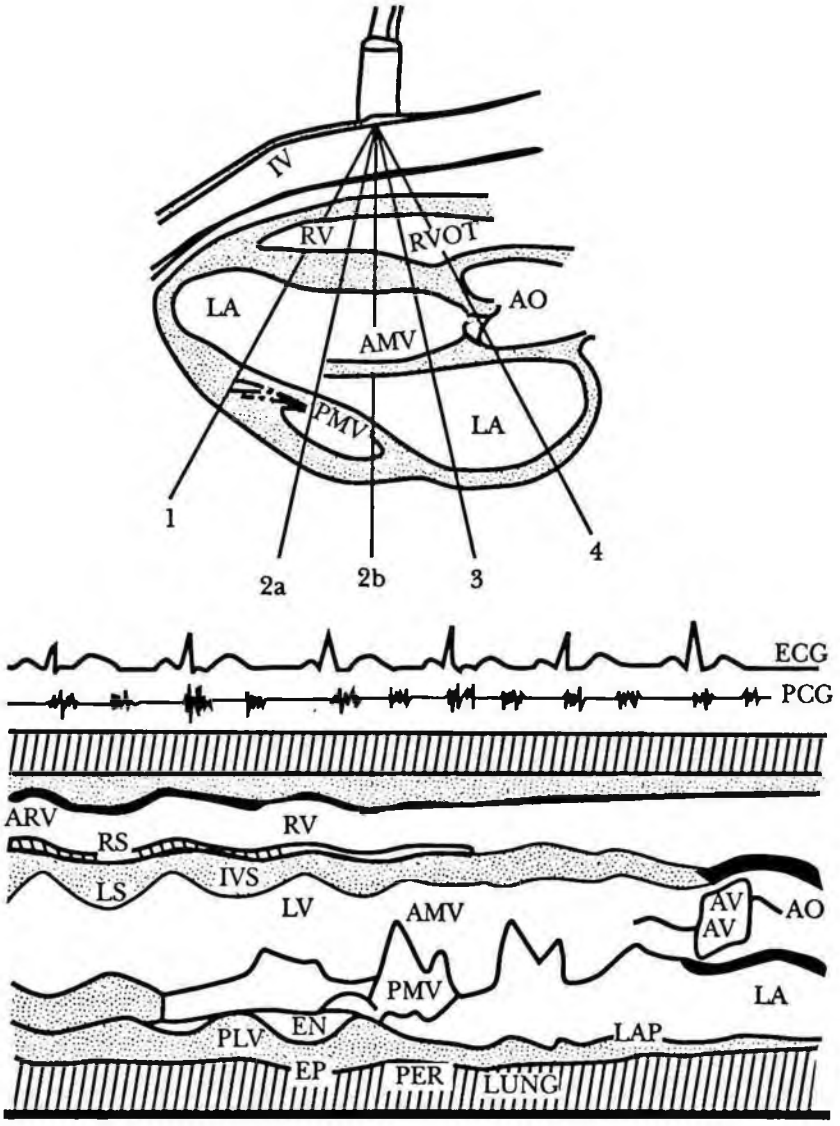

Fig. 18.2 Sketch map of M-mode echocardiography of each area of the heart by longitudinal axial scanning on the precardiac region. ECG — Electrocardiogram; PCG — Phonocardiogram; W — thoracic wall; ARV — anterior wall of the right ventricle; RV — right ventricle; RS — right septal surface of the interventricular septum; LS — left septal surface of the interventricular septum; IVS — interventricular septum; LV — left ventricle; AMV — anterior leaf of mitral valve; PMV — posterior leaf of mitral valve; AV — aortic valve; AO — aorta; PLV — posterior wall of left ventricle; EN — endocardium; EP — epicardium; PER — pericardium; LAP — posterior wall of the left atrium; LA — left atrium.

18.1.2.1. *Precardial Examination*

The patient assumes the supine position or semi-lying position, usually beginning from the 2nd intercostal space along the left border of the sternum, facing inwards and outwards, from superior to inferior, examining each intercoastal space usually from the 2nd–5th intercostal space. An emphysema patient is to be examined in the 5th–7th intercostal space, closely along the sternum, taking care to obtain a standard diagram of each region.

(a) Examination of wave groups at the base of the heart (4 areas)
The probe is usually placed on the second to the third intercostal space, 2–3 cm away from the left border of the sternum. Let the probe be perpendicular to the thoracic wall as much as possible, and let it face the obliquely superior (right superior) position. Emphysema patients may assume the left decubitus position. Wave groups at the base of the heart display the outflow tract of the right ventricle, the root of the aorta and the internal calibre of the left atrium.

The important points of the examination are to obtain standard diagrams:

(i) Clearly display the intimal surface of the anterior wall of the right ventricle;
(ii) Synchronous motion of the anterior and posterior wall of the root of the aorta;
(iii) The aortic valve is clearly displayed at the centre of the root of the aorta, or display the closing point or opening point of the aortic valve;
(iv) Clearly display the curve of the posterior wall of the left atrium. A normal internal calibre of the outflow tract of the right ventricle is 20–30 mm, the internal calibre of the root of the aorta is 25–35 mm and the internal calibre of the left atrium is 25–35 mm. In normal adults, the ratio of the internal calibre between the outflow tract of the right ventricle, root of aorta and left atrium is 1 (Fig. 18.3).

(b) Examination of wave group of the mitral valve (area 2 and area 3)
Usually, the examination is done in the 3rd–4th intercostal space along the left border of the sternum. Let the probe be placed from the right superior, obliquely facing the left inferior a little after examination of the aortic valve. If the sound beam is only passing

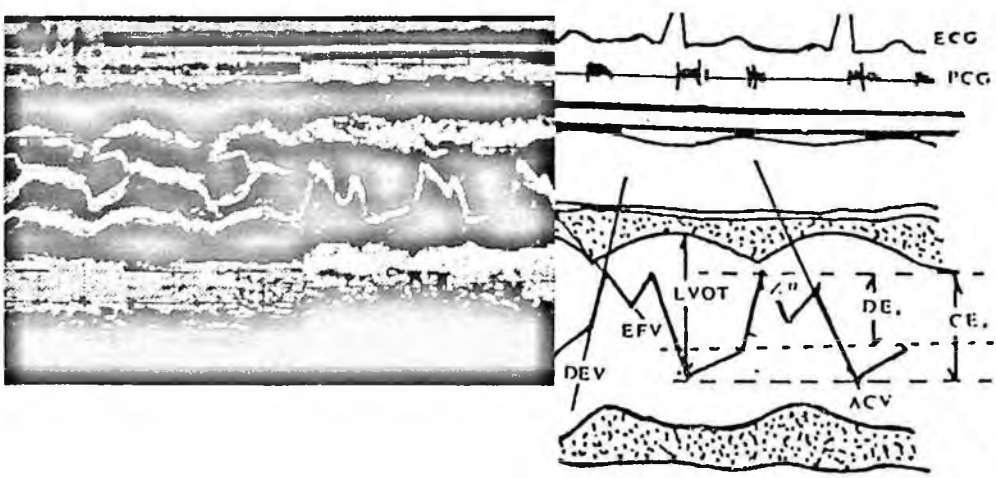

Fig. 18.3 M-mode echocardiography of wave group of the base of the heart (left) and curve of the anterior leaf of the mitral valve (right).

through the anterior leaf of the mitral valve, the motion curve of the anterior leaf of the mitral valve will be displayed, i.e. area 3. Here the amplitude of the motion of the anterior leaf of the mitral valve is the largest. Its anterior is the outflow tract of the left ventricle and membranous portion of the interventricular septum. Its posterior is the motion curve of the atrio-ventricular ring. The normal motion of the anterior leaf of the mitral valve at the systolic stage presents a straight line inclining gradually forward — that is the C–D segment. At the diastolic stage, a double hump sign is presented, namely the E hump, dividing the opening of the anterior leaf of the mitral valve when the ventricle is on diastole, and the A hump, produced by contraction of the left atrium. CE represents the biggest amplitude of the motion of the mitral valve, the normal range is 20–30 mm. The EF segment is at the diastolic stage, after the opening of the mitral valve, blood is rapidly evaculated from the left atrium. A drop in pressure of the left atrium causes the anterior leaf of the mitral valve to drop rapidly and form a curve. The speed of dropping is related to the compliance of the left ventricle, and the amount of flow of the mitral valve orifice. The normal speed of dropping of EF is over 70 mm/sec (Fig. 18.3).

If the sound beam is allowed to pass through the anterior and posterior leaf of the mitral valve, curves of the anterior and posterior leaf of the mitral valve will be displayed, i.e area 2. It is further divided into area 2a and area 2b. The former displays the right ventricle, atrioventricular septum, left ventricle and posterior wall of the left ventricle more completely. The normal internal calibre of the right ventricle is 10–20 mm, the internal calibre of the left ventricle at the end of a diastole is 45–55 mm, the internal calibre of the left ventricle at the end of systole is 25–35 mm, the thickness of the atrioventicular septum at a diastole is 6–12 mm, and the thickness of the anterior wall of the right ventricle is 2–5 mm. The features of the diagram in this area are as follows: within the left ventricle one can find movements of the chordae tendieae of the mitral valve, the structure displayed in area 2b is similar to that in 2a, but within the left

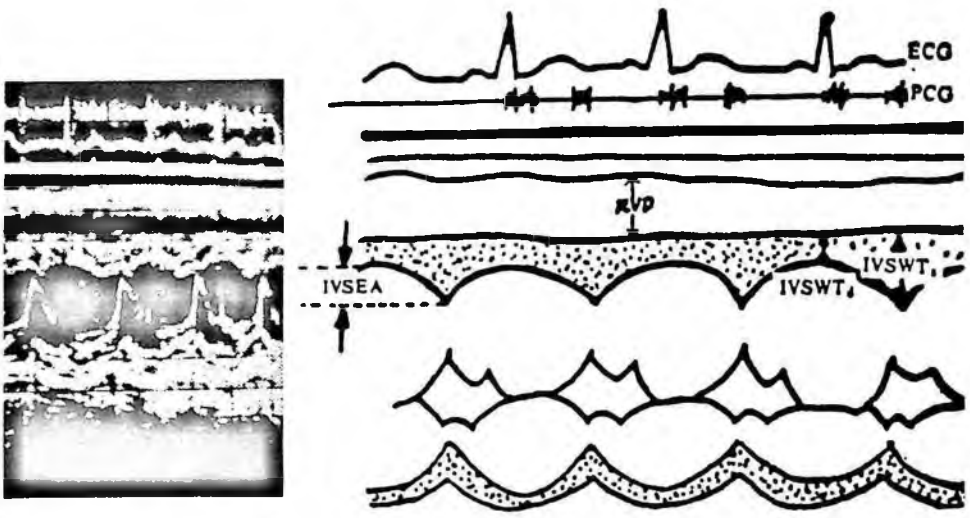

Fig. 18.4 M-mode echocardiography of the motion curve of the anterior and posterior leaves of the mitral valve.

ventricular cavity one can find complete motion curves of the anterior and posterior leaves of the mitral valve (Fig. 18.4).

(c) Examination of the wave of the ventricle (area 1)
In general, when the anterior and posterior leaves of the mitral valve are found, turn the probe towards the external inferiorly. When curves of the mitral valve gradually disappear or only the E hump is seen, this is the wave group of the ventricle, namely area 1. This area can only display a part of the right ventricle, the left ventricle at the apical region and the interventricular septum.

(d) Examination of the wave group of the tricuspid valve (area 5)
Place the probe on the 2nd–3rd intercostal space along the left border of the sternum. First, find the echo of the mitral valve, then incline the probe inwards, namely in the direction of the right foot, the wave group of the tricuspid valve will hence be examined (area 5). The motion curve is similar to that of the mitral valve. However, the tricuspid curve is close to the thoracic wall, its posterior is the atrioventricular septum or the posterior wall of the right atrium, whereas the mitral valve is far away from the thoracic wall and its anterior is the interventricular septum.

(e) Examination of the pulmonary valve (area 6)
After examining the root of the aorta or mitral valve, turn the probe to the right, then the superior motion curve of the posterior leaf of the pulmonary artery valve can be displayed. The normal depth of wave *a* of the pulmonary artery valve is 2–4 mm, the *cd* segment is the curve of the horizontal straight line inclined upwards (Fig. 18.5).

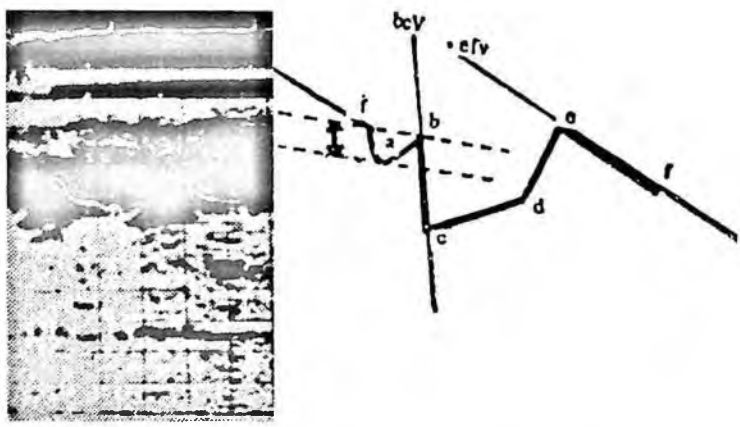

Fig. 18.5 M-mode echocardiography motion curve of the valve of the pulmonary artery.

18.1.2.2. *Examination on the Suprasternum Fossa*

The patient assumes the sitting position or semi-lying position, his head may be shifted to one side in order to relax the neck. Place the probe on the suprasternal fossa, pointing to the inferior or deviating a bit to the left. The aortic arch, right pulmonary artery and the curve of the left atrium can then be displayed. A normal internal calibre of the right pulmonary artery is not over 18 mm.

18.1.2.3. *Examination on the Infra Xyphoid Process*

Place the probe below the xyphoid close to the left costal margin, with the sound beam pointing to the heart. The wave group of the right ventricle, the atrioventricle, aorta and the ventricle will then be detected.

18.2. TWO-DIMENSIONAL ECHOCARDIOGRAM

18.2.1. Position of Examination and Standard of Images

18.2.1.1. *Commonly used Examination Positions for Two-Dimensional Echocardiogram*

(a) Precardial region, also called the parasternal (refering to the left). If it is the right side, additional explanation is necessary.
(b) Apical region, refering to the apex beat at the left side.
(c) Infra xyphoid process region (also called hypocostal region).
(d) Supra sternal region.

18.2.1.2. *Standards of the Image for Two-Dimensional Echocardiogram*

The image plane is divided into long axial section, short axial section and four-chamber view in accordance with the tomography of the heart.

The apical portion of the sector image (sector apex) is the near field echo. The far field of arc spread out of the sound beam (sector arc) is the far field echo, it is located inferior to the oscillogram. Sometimes, when the four-chamber view image is displayed, turn the image upside down (without a change in the left and right positions) and let the sector arc be on top and the sector apex below. The standard position of each tomography is:

(a) Long axial section
The long axial section of the precardial region is the long axial tomography of the heart. The plane of the sound beam is perpendicular to the physical surface of the anterior thoracic wall, and is parallel to the long axis of the heart. Customarily, the left image displays the pedal end, that is the structure of the apex of the left ventricle (this standard position is the reverse of the display of the abdominal sonogram). Since the long axis of the heart has a definite inclination, there is a definite interposition angle between the long axial section and the actual anatomical sagital section.
(b) Short axial section
The short axial section of the precardial region is the cross-section of the heart by scanning plane. The sound beam surface and physical surface of the anterior thoracic wall is perpendicular to the long axis. The upper and lower end of the image indicate the anterior and posterior of the heart, respectively. The left image shows the right side of the heart, the right image shows the structure of the left side of the heart (this standard position is identical to the abdominal sonogram).
(c) Four-chamber view
The plane of the sound beam is perpendicular to the long axis and short axis of the heart, and nearly parallel to the anterior thoracic wall. The sector apex is the apex of

the heart, and the sector arc is the base of the heart. The left image shows the right side of the heart, while the right image shows the left side of the heart. If the sector is placed reversibly, the superior and inferior of the image are practically identical to the anatomy.

In the clinical description of the position of the image, in order to avoid confusing the left and right side of the image with the left and right position of the actual anatomy, all anatomical positions are used as the standard. For example, the big blood vessel in the short axial section of the normal base of the heart is still described, according to the anatomy, as the "pulmonary artery valve left anterior to the aorta".

18.2.2. Commonly Used Sectional Images of the Heart

18.2.2.1. *Precardial (Para Sternum) Section*

(a) Long axial section

Along the longitudinal axial section of the heart, according to different planes of the sound beam, it is further divided into:

(i) Long axial section of left ventricle

The probe is placed on the 3rd–4th intercostal space along the left border of the sternum in order to allow the plane of the sound beam be nearly parallel to the linked line of the right thoracoclavicular joint with the left papilla. The sonogram displays the right ventricle, left ventricle, left atrium, interventricular septum, mitral valve and the root of the aorta. The size of the left ventricle and left atrium, the motion and continuity of the interventricular septum can then be observed. Also, the condition of the mitral valve and the root of the aorta can be clearly observed;

(ii) Long axial section of the root of the aorta

Similar to above-mentioned long axial section of left ventricle. When the plane of the sound is from the right shoulder of the patient to the left side of the abdomen, one can clearly observe the long axial image of the root of the aorta, the aorta valve, the outflow tract of the right ventricle, left atrium, and the outflow tract of the left ventricle (Figs. 18.6 and 18.7);

(iii) Long axial section of the outflow tract of the right ventricle

After displaying the section of the root of the aorta, further rotate the probe clockwise, inclining upwards, then the entire outflow tract of the right ventricle, pulmonary artery valve and proximal end of the pulmonary artery trunk can be displayed. To its posterior is the left ventricle and part of the mitral valve;

(iv) Long axial section of the inflow tract of the right ventricle

After examining the section of the root of the aorta, incline the plane of the sound beam internally and inferiorly, one can then oberve the right ventricle, the inflow tract of the right ventricle, right atrium and the tricuspid valve.

Through the parasternal long axial section, one can evaluate the condition of the root of the aorta, the aortic valve, left atrium, left ventricle, interventricular septum, outflow tract of the right ventricle and the pulmonary artery valve.

(b) Short axial section

After obtaining the long axial section of the precardiac region, turn the probe 90° clockwise and let it be perpendicular to the long axis. Then one will obtain every sectional image of the short axis of the left ventricle. Rotate the probe slightly or move

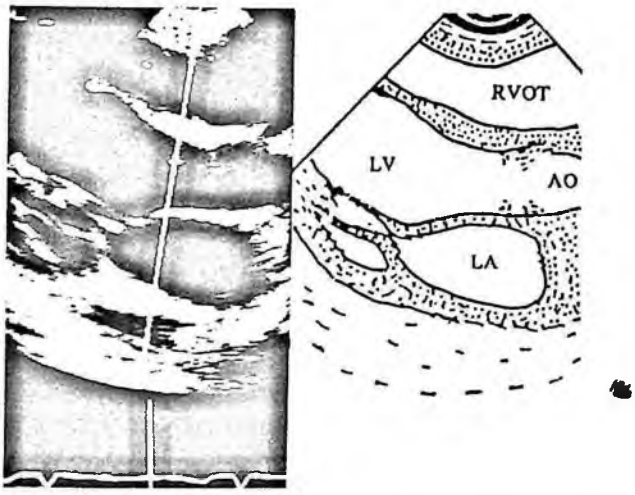

Fig. 18.6 Long axial section of the root of the aorta (systolic stage).

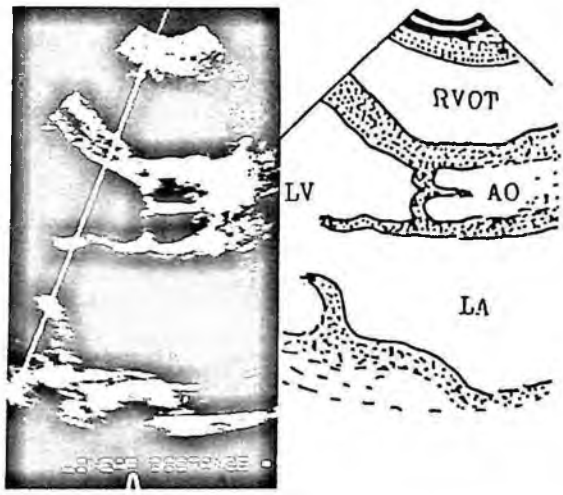

Fig. 18.7 Long axial section of the root of the aorta (diastole).

it high and low slowly, then short images of the heart at different levels will be obtained (Fig. 18.8).

(i) Short axial section of the apex
Incline the probe to the apex of heart or move the probe down and place it directly on the pulsating point of the apex in order to get the drawing. At this place, the calibre of the cardiac cavity displayed is the smallest and the ventricular wall is the thickest. It is valuable for observing the degree of hypertrophy of the myocardium at the apex of the heart (Fig. 18.8.1).

(ii) Short axial section of papilla muscle and chordae tendineae level
After obtaining the sonogram of the short axial section of the apex of the heart, let the plane of the sound beam be slightly perpendicular to the thoracic wall. One

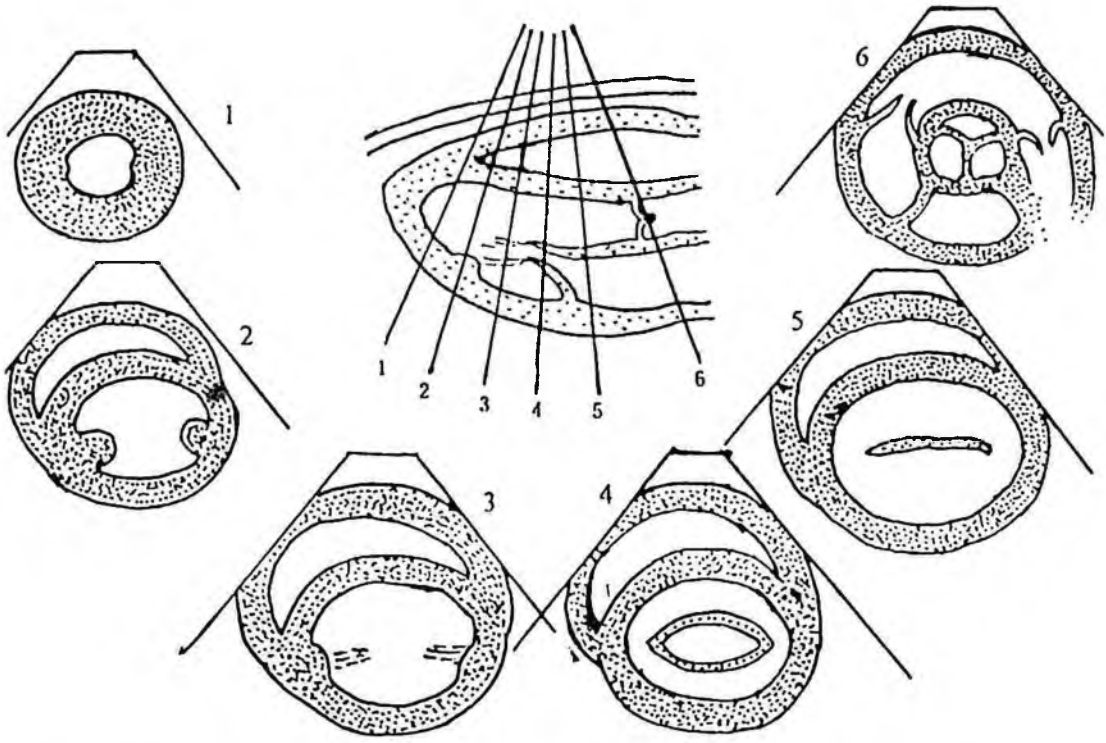

Fig. 18.8 Sketch map of the short axial section of the heart at the pericardial region; (1) Short axial section of the apex; (2) Short axial section of the papilla muscle; (3) Short axial section of the chordae tendineae level; (4) Short axial section of the mitral valve level; (5) Short axial section of the anterior leaf of the mitral valve level; (6) Short axial section of big blood vessel level.

will then obtain the short axial sectional image of the papilla muscle or chordae tendineae level. In the 3–5 and 8–9 point of the image, one may find two round mass images of prominence protruding into the vacuum cavity from the ventricular wall. They are the posterior internal and anterior external papilla muscles, respectively. If it is at the chordae tendineae level, one may find fine, strip-like echoes of the chordae tendineae (Figs. 18.8.2 and 18.8.3). The interventricular septum is on the left anterior side of the image, it appears like a bow. At this section, one may observe if the papilla muscle is hypertrophied, whether there is laceration of the papilla muscle or chordae tendineae and the condition of interventricular septum at the apical region.

(iii) Short axial section of the anterior and posterior leaves of the mitral valve

Let the probe continue to assume an upward inclination, practically perpendicular to the physical surface of the thoraic wall. The left and right ventricular cavity, interventricular septum, and anterior and posterior leaves of the mitral valve can be displayed. When the anterior and posterior leaves of the mitral valve open at the diastolic stage, the echo is in the shape of a fish mouth, and when they close at the systolic stage, the echo is linear. The left side of the image is the anterior commissure and right side is the posterior commissure. The left superior part of the image is the semi-lunal shape in the right ventricle. At the short axial section,

both the greater portions of the left and right ventricle can be displayed, forming a rather complete short axial sectional image of the heart. The internal calibre of right and left ventricle, the motion of the interventricular spetum and ventricular wall, the morphology of the mitral valve and the size of valvular orifice can be observed (Fig. 18.8.4).

(iv) Short axial section of the outflow tract level of the left ventricle
After tracing the short axial section of the mitral valve, incline the probe upwards slightly to display the short axial section of the outflow tract of the left ventricle. In the image, superior to the anterior leaf of the mitral valve is the outflow tract of the left ventricle and inferior to it is the left atrium (Fig. 18.8.5).

(v) Short axial section of the big blood vessel
The probe is placed on the 2nd–3rd intercostal space along the left border of the sternum, right anterior to the big blood vessel at the base of the heart. The position of examination is nearly parallel to the linked line of the left shoulder with the right costal arch. Alternatively, after the examination of the short axial section of the outflow tract of the left ventricle, let the probe incline to the left superior, then the short axial section of the big blood vessel at the base of the heart will be displayed (Fig. 18.8.6). The aorta is a round, strong pulsating echoless dark area, three aortic valves close at the diastolic stage presenting a "Y" shape. At the systolic stage, the valvular leaf echo disappears or presents an inverted triangle. The outflow tract of the right ventricle encircles the anterior part of the aorta; the left atrium is posterior to the aorta; the tricuspid valve is in the middle of the left side of the image (about point 9), inferior to the tricuspid valve is the right atrium, superior to the tricuspid valve is the right ventricle, and between the right and left atrium is the interatrial septum; the pulmonary artery is anterior to the right side of the image (point 3), its posterior continuity is the trunk of the pulmonary artery. Sometimes, one may find an image of the left and right branch of the pulmonary artery.

18.2.2.2. *Section on the Apical Region*

(a) Section of the four-chamber
The patient assumes a semi-left decubitus position, the probe is placed on, or near, the apical pulsation of the heart. The sound beam faces the internal, superiorly pointing to the right shoulder of the patient. The sound beam takes oblique sections of the heart from the apex to the base of the heart, passing through the plane of mitral valve orifice to the tricuspid valve orifice (Fig. 18.9). At this moment, the four-chamber view, atrioventricular septum, interventricular septum and the crux interset are displayed. The anterior leaf of the mitral valve is attached to the cephalic end of the left antrioventricular groove near the membranous septum, the tricuspid septal leaf is attached to the interset of the middle superior of the membranous portion of interventricular septum. The attachment point of the tricuspid valve is lower than the mitral valve by about 8–10 cm. The plane of the four-chamber at the apex is nearly parallel to the atrioventricular septum due to the plane of the sound beam. Therefore, it often induces echo drop-out, resulting in the appearance of the "pseudo defect" sign of the atrioventricular septum. It deserves attention.

If the plane of sound beam is inclined forward, it can display the four-chamber and the root of the aorta. One can also display the aortic cavity in communication with the outflow tract of the left ventricle. At this point of time, the aortic valve can be displayed clearly. This section is also called the five-chamber view section. This section is often used for observing the crossing of the aorta and whether there is regurgitation of the aortic valve by Doppler examination.

(b) Section of two chambers of the apex
The position is similar to the four-chamber section. Turn the plane of the sound beam about 90° clockwise, nearly parallel to the interventricular septum. It will display the image of the two-chamber of the left ventricle and left atrium.

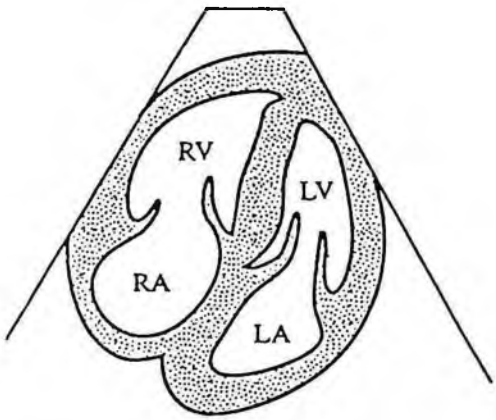

Fig. 18.9 Diagram of the section of four-chamber: LV — left ventricle; LA — left atrium; RV — right ventricle; RA — right atrium.

18.2.2.3. *Section on the Infra Xyphoid Process*

(a) Section of the inferior vena cava and hepatic vein
The probe is a little to the right side of the abdominal median line below the xyphoid process. Let the direction of the sound beam be parallel to the median line, deviating a little to the right. It can then display the inferior vena cava, the left lobe of the liver and the left branch of the hepatic vein. The inferior vena cava drains into the right atrium, and the atrioventriculac septum and tricuspid valve can be displayed. At this section, one can observe the condition of the inferior vena cava. It has practical values in evaluating the functions of the right side of the heart.

(b) Subxiphoid four-chamber view
The probe is placed below the xyphoid process, the plane of the sound beam is facing upwards, pointing between the suprasternal fossa and left supraclavicular fossa. The section of the four-chamber is hence displayed, and, it is similar to the section on the left parasternal region. This section will overcome the phenomenon of a drop-out in the echoes of the auricular septum. It is an important section used for the examination of the auricular septum defect.

18.2.2.4. *Section on the Suprasternal Fossa*

(a) Long axial section of the aortic arch
Place the probe on the suprasternal fossa, with the plane of the sound beam facing downwards, and slightly posteriorly parallel to the aortic arch. The aortic arch and descending aorta can then be displayed. The important branch of the aortic arch is the innomiate artery. The left common carotid artery and left infraclavicular artery can also be displayed. Inferior to the aortic arch is the short axial face of the right pulmonary artery.

(b) Short axial section of the aortic arch
Place the probe on the suprasternal fossa, with the plane of the sound beam perpendicular to the aortic arch, then the round short axial section of the aortic arch, long axis of the right pulmonary artery, trunk of the pulmonary artery, the left pulmonary artery and left atrium can be displayed.

Through the long and short axial section of the suprasternal fossa and aortic arch, one can observe the lesion of dissecting aneurysm of the aorta and aortic stenosis and the lesion of the right pulmonary artery and trunk of the pulmonary artery. Sometimes, the conditions of patent ductus atteriousus and the superior vena cava can also be observed.

Similar to the ultrasonic imaging examination of the abdominal viscera, for the ultrasonic sectional diagnosis of the heart one must also be familiar with the intracardiac anatomical structure, its inter relations, and with the normal fundamental image of each section, so that the position and the nature of the lesion can be determined, providing reliable and valuable data for clinics, and forming an important basis for the diagnosis of heart diseases. Now, we can sum up the sectional images commonly used in ultrasonic sectioning of the heart:

- Precardic region (parasternal)
  - long axis
    - section on the root of the aorta
    - section on the left ventricle
    - section on the outflow tract of the right ventricle
    - section on the inflow tract of the right ventricle
  - short axis
    - section on the apical level of the left ventricle
    - section on the level of the papilla muscle and chordal tendinea
    - section on the level of the mitral orifice
    - section on the level of outflow tract of the left ventricle
    - section on the level of the big blood vessel
- Apical region
  - section on the apical four-chamber
  - section on the apical five-chamber
  - section on the apical two-chamber
- Infraxyphoid region
  - section on the inferior vena cava and hepatic vein
  - section on the subxiphoid four-chamber
- Suprasternal region
  - long axial section on the aortic arch
  - short axial section on the aortic arch

18.3. COMMONLY USED CARDIAC ACOUSTIC CONTRAST EXAMINATION METHOD

Acoustic constrast examination uses percutaneous puncture or cardiac catheterization to instill a strong ultrasonic reflection agent into the vein, artery or cardiac cavity, so as to let the blood in the heart or blood vessel have cloudy echo reflections. This is done in order to raise the rate of diagnosis of intracordiac shunt and valvular regurgitation.

18.3.1. Common Acoustic Contrast Medium and the Method of Utilization

18.3.1.1. *Acoustic Contrast Medium Containing Carbon Dioxide*

(a) Gasesous CO_2
Have a direct intravenous infusion of 1–3 ml of pure gaseous CO_2, or first inspire 5–10 ml of 5% glucose fluid (or normal saline), then 1–3 ml of inspire gaseous CO_2. After shaking (without expelling the gas), infuse directly into the vein.

(b) Mixture of sodium bicarbonate and vitamin C
Mix 5 ml of 5% soldium bicarbonate and 2 ml (or 5 ml) of specially-prepared 5% vitamin C (pH 2.5) together, and then inject intravenously. Usually, gas is produced to the maximum within 2 minutes and it may last for about 6 minutes.

(c) Mixture of sodium bicarbonate and hydrochloric acid
Take 2–4 ml of 5% sodium bicarbonate purchased from the market, then inspire 0.5 ml of 1% hydrochloric acid injection fluid. Mix together (without expelling the gas), and then infuse intravenously.

(d) Mixture of sodium bicarbonate and acetic acid
Slowly mix 5 ml of 5% sodium bicarbonate and 1 ml of 5% acetic acid in a syringe. After slight shaking, rapidly inject intravenously. This may be repeated once after every 5 minutes for 5–6 times.

18.3.1.2. *Acoustic Contrast Medium Containing Oxygen*

This is a H_2O_2 method. Use a 1-ml syringe (to inspire 3% H_2O_2), a 50-ml syringe (to inspire normal saline or glucose fluid), a scalp injection needle and a 3-way switch. First, intravenously inject glucose fluid or normal saline to keep the venous flow from being blocked. Then use a 1-ml syringe to inspire 3% 0.3–0.5 ml of H_2O_2 (adult). Through the 3-way switch, infuse it into the vein, turn the 3-way switch immediately, and rapidly infuse 5–10 ml of glucose fluid intravenously, then later by slow dripping. Repeat once after every 3–5 minutes, for 4–5 times.

18.3.1.3. *Other Acoustic Contrast Media*

There are many kinds used clinically such as iodized contrast medium, indocyanoblue green, autoblood, distilled water, 5% glucose fluid, normal saline, ether and dehydrochloric acid.

18.3.2. Clinical Value and Indication

M-mode ultrasonic cardiogram for the acoustic contrast examination can be used to analyze clearly the time phase and the order in which the contrast medium enters each part of the cardiac cavity and blood vessel. It can also analyze the direction and slope function of the reflection motion of the contrast medium. The feature of sectional ultrasonic cardiac acoustic contrast examination is rather explicit in space localization. It is convenient for observing the direction and amount of shunt and regurgitation, and can carry out the examination of the function of the right heart. The chief values of clinicial application are:

(a) Determination of the outline and size of the cardiac cavity, the thickness of the ventricular wall and inter-anatomical relationship;
(b) Examination of the intracardiac shunt and regurgitation of the valve;
(c) Measurement of cardiac functions such as the circulation time from the arm to the heart and the evacuation time of the right ventricle;
(d) Observation of malformed drainage of the big vein, such as diagnosing the rudimentary left superior vena cava.

18.3.3. Contraindication and Precautions during Cardiac Acoustic Contrast Examination

It is generally considered that the contrast medium used clinically nowadays are relatively safe. Having clinically observed more than 20 to 30 thousand cases in China, the rate of success is rather high. There are no serious complications discovered yet. According to a majority of reports, its relative contraindications are:

(a) Severe cardiac insufficiency or severe cardiac failure with no tolerence for the contrast examination;
(b) The patient has allergic reactions to the acoustic contrast medium, such as being allegic to an intravenous injection of vitamin C;
(c) The patient has serious cyanosis.

Even though the side effects of the cardiac acoustic contrast medium are mild, with a high level of safety, for the sake of preventing the occurrence of untoward effects when doing the acoustic contrast examination, and to raise its efficiency, the following items should be noticed:

(a) The quality of the contrast medium should be good, without the presence of impurities;
(b) The speed of injection must be quick. Usually, the injection should be finished within 1 to 2 seconds;
(c) The injection is usually repeated 3–5 times, the interval between two injections is usually determined by the complete disappearance of the intracardiac contrast medium's reflection and the patient not having any untoward effects;
(d) The ideal vein for injection should be the basilic vein or brachiocephalic vein (the big veins at the elbow);

(e) On adding vitamin C or acetic acid into sodium bicarbonate, carbon dioxide gas is immediately produced. It should not be expelled from the syringe, and should be infused into the vein altogether.
(f) Pay attention to the untoward effects induced by the injection of the contrast medium.

18.4. DOPPLER ECHOCARDIOGRAM

18.4.1. Fundamental Principles of the Doppler echocardiogram

In 1842, Doppler, an Austrian physicist, discovered that when there is movement of the sound source and the object under examination is in the opposite direction, the alteration of the audio frequency will be induced. This sign is called the Doppler effect. When the sound source and the object are in the same direction of movement, the audio frequency increases, and when these two are in the opposite direction of movement, the audio frequency decrease.

The Doppler echocardiogram is based on the Doppler effect and the rule of shifting frequency. It uses ultrasound waves to examine the blood flow in the heart and the big blood vessel. The main body of movement in the blood of the heart and blood vessel is the red blood cell (RBC). Using the reflecting and scattering function of the RBC in ultrasound, one can obtain the difference between the ultrasound frequency of scattering received and the ultrasound frequency emitted from the probe, namely, the Doppler shifting frequency, which is expressed in the following formula:

$$f_d = \pm \frac{2V_s \cdot \cos\theta}{c} \cdot f_0$$

$$f_d = \frac{2V \cdot \cos\theta}{c} \cdot f_0 \ ,$$

where Vs is the speed of RBC, c is the sound speed in blood flow, f_0 is the frequency of ultrasound emitted and θ is the interposition angle between the axial line of place of sound beam and the cell vector (blood flow).

Since the speed of transmission of ultrasound in the soft tissues of the human body is comparatively close to that in blood, if the emission frequency is constant, θ is kept constant, then the speed of movement, the speed of blood flow is $V = C \cdot f_d / 2f_0 \cos\theta$. The amount of blood flow is $Q = A \cdot V$ (Q is the amount of blood flow, A is the cross-sectional area of the internal cavity of the blood vessel, V is the speed of blood flow). This may serve as the quantitative analysis for the diagnosis of angiocardiopathy.

If the ultrasound frequency emitted from the probe is 3 MHz and the angle is equal to $0(\cos\theta = 1)$ then the speed of blood flow, V, will be simplified as:

$$V = \frac{1}{4} f_d \ .$$

At this point of time, f_d is the shifting frequency, with KHz as the unit, and V is the speed of blood flow, with meter/second (m/s) as the unit.

18.4.2. Common Mode of Dopper Echocardiogram

18.4.2.1. *CW Doppler*

The probe possesses two transducers, one of them can continuously emit ultrasound waves, and the other one will continuously receive the returning sound waves. An advantage of this is being able to measure the high speed of blood flow without limitations. However, it will record all the signals of the motion speed of the blood cell in the transmission of the sound beam, but there are no ways to ascertain the location.

18.4.2.2. *PW Doppler*

The probe has only one transducer, it can emit short array ultrasound waves intermittently, it can also receive the intermittently-returning sound waves due to reflection. Due to the selection of the general control pulse emission from a distance and the delay in the recovery time, the distance of examination by Doppler is selected, hence it is called distance general control Doppler. Having the function of resolving distance, selecting the course and taking the sample, it therefore locates the blood flow for diagnosis. The main defect is that the maximum shifting frequency measured or the speed of blood flow is limited by the pulse repeat frequency and the depth of sampling. When the shifting frequency is over 1/2 of the pulse repeat frequency, it will produce frequency aliasing. When taking a sample in the far field, due to the increase in distance of the to-and-fro movements of the sound beam and the time required, the pulse repeat frequency of the far field is low. The to-and-fro frequency that can be displayed is also limited, namely, it can measure the maximum shifting frequency but cannot produce the aliasing frequency.

18.4.2.3. *CDFI*

This technique is the technique of combining the anatomical images of two-dimensional ultrasonic cardiogram with the two-dimensional Doppler color code imaging. The features are:

(a) Overlapping the message of blood flow on respective cross sections of two-dimensional ultrasound or M-mode ultrasound cardiogram;
(b) Using different color and depth to display the direction and speed of blood flow. Many equipment use the red color to display the blood flow facing the probe and the blue color to display the blood flow leaving the probe. The brightness of the color is great when the speed of blood flow is high, otherwise the brightness is little. Disorderly blood flow is represented by the mosaic pattern of red and blue;
(c) In accordance with the color displayed in the blood, the area, outline, length and width of the blood flow bundle can be determined;
(d) One can analyse the change in the speed of blood flow at different time phases of the cardiac cycle in combination with the electrocardioscillogram, providing valuable data for studying blood dynamics in the heart.

18.4.3. Normal Doppler Echocardiogram

Nowadays, Doppler Ultrasound is displayed by frequency sounds or images. Owing to the frequency emitted from the Doppler ultrasound examination, the range of shifting frequency caused by normal or abnormal blood in the heart is about 400–5000 MHz, which is just within the range of the audible frequency of sound. So it can be displayed by the frequency of sound, and this is the sensitivity index of Doppler ultrasound examination. By this we can identify normal and abnormal blood flow, determine whether the sound beam has examined the efflux, and whether the shifting frequency examined is the true maximum shifting frequency. In the case of the image-displaying method, the zero intersecting examination method, displayed by straight strip image of time interval, used in the past is now replaced by FFF transferred three-dimensional spectrum analytic displaying method. The horizontal axis indicates time, the vertical axis indicates shifting frequency or speed of flow, the sagital axis indicates strength, and is displayed by a gray scale.

In normal blood flow, the RBC moves in coincidal direction and the speed of flow is called the laminated flow. During the Doppler ultrasound examination, the RBC moving in the same direction and with identical speed in the laminated flow will have a similar gain and size of shifting frequency, resulting in audible signals presenting a tender musical tone. The spectrum analysis image presents a narrow band smooth image. In general equipment, the frequency spectrum of the blood flow facing the direction spectrum is upward. If the direction of blood flow is opposite to the direction of the probe, the frequency spectrum is downward (inferior to O line).

Normal flow color Doppler flow imaging has a definite regularity. At diastole, the high speed flow bundle appears in the mitral and tricuspid valve orifice, representing blood from the left and right atrium flowing into the left and right ventricle. In the mitral and tricuspid valve orifice and at the inflow tract of the left and right atrium, one can also find an evenly-distributed red flow bundle (facing the probe), whereas there is no flow signal at the semilunar valve. At systole, blood flows from the left and right ventricle to the aortic and pulmonary artery. The highest speed of flow appears at the semilunar valve orifice, presenting evenly-distributed blue flow bundle (away from the probe), and there is no flow signal at the trioventricular valve orifice. A normal flow signal is big in surface, presenting mono-color, and indicating the laminatd flow of blood and the normal calibre of the valve.

18.4.4. Doppler Ultrasonic Examination Technique of Flow Dynamics

(a) Measurement of pressure differences of crossing valve
After some studies, the simplified Bernoulli equation can be used to calculate the pressure difference of crossing valve:

$$\Delta P(\text{mmHg}) = 4 \cdot V^2\ (\text{m/s})\ ,$$

where P is the biggest instant pressure difference of the valvular orifice, V is the narrow point of the valvular orifice or the greatest speed of flow in the lower side.

During the examination one should note that:

(i) The Doppler sampling container should be placed at the center of the ejection flow, where the valvular orifice is stenosed, to measure the greatest speed of flow;

(ii) Let the interposition angle between the examination sound beam and ejection flow center be equal to zero or as near to zero as possible (not exceeding 20° at the maximum). Let the error decrease to less than 10%;

(iii) It is preferable to combine with continuous wave Doppler or extend distance and general control pulsed Doppler, to measure the greatest speed of blood flow.

(b) Estimation of the area of the valvular orifice

In accordance with the Gorlin equation used in cardiac catheterization examination, applying the result of sectional ultrasonic imaging and Doppler ultrasonic examination, the area of valvular orifice can be calculated as:

$$VA_a = \frac{(Qa)/(SEP_a)}{K\sqrt{\Delta Pas}}, \tag{1}$$

where VA_a is the area of the aortic orifice, Qa is the amount of flow through the aortic orifice, SEP_a is the ejection time at systole, K is a constant, and ΔPas is the average pressure difference of the aortic orifice at systole.

This method is complicated and is not widely used in clinics.

In addition, the following formula can be used for calculation:

$$AVA = CO/SEP \times MV, \tag{2}$$

where AVA is the area of the aortic orifice, CO is the cardiac output, SEP is the ejection time at systole and MV is the average speed of blood flow at the orifice.

If we use $P = 4V^2$ to calculate the pressure in the Gorlin formula, then we will get $AVA = CO/0.9 \times SEP \times$ the greatest speed. The measurement of the area of the aortic orifice has good positive interrelation with the results of catheterization.

Although the pressure difference calculated by Bernouli has good interrelation with the results of catheterization, the pressure difference will be influenced by the cardiac output and heart rate. Therefore, measuring the area of the valvular orifice may be more accurate than the pressure difference. But using the Gorlin equation, if it is complicated with incompetency, rather big errors will be induced. Therefore, some authors advocate the use of "pressure substract half the time" to calculate the area of the mitral orifice of mitral stenosis.

$$\text{Area of mitral orifice } (\text{cm}^2) = \frac{220}{\text{pressure subtract} \cdot \text{half of time (m/s)}}. \tag{3}$$

This method will not be influenced by the heart rate, cardiac output and complication of incompetency.

(c) Measurement of the pressure of the pulmonary artery

Hatle used Doppler ultrasound and phonocardiogram record synchronously to measure the time interval between closing the pulmonary valve (PC) and opening the tricuspid valve (TO) so as to calculate the pulmonary artery pressure. This method has the

features of being non-traumatizing and strong repetition. Compared with the compound method, it has very high interrelation.

(d) Measurement of the systolic time interval of the right ventricle

The Union Hospital, affiliated to Fujian Medical University, used the pulsed Doppler Frequency Spectrum and electrocardiogram synchronously to scan, so as to measure the early stage of ejection of the right ventricle (RPEP), and the ejection time of the right ventricle (RVET) (Fig. 18.10). The result of this clinical application showed that when there is high pressure in the pulmonary artery, RPEP extends and RVET shortens, causing the ratio of RPEP/RVET to increase, and this has a definite value in estimating the pulmonary artery pressure. Table 18.1 shows the results of measuring the right ventricle systolic time interval of a group of normal people and a group of patients with pulmonary heart disease.

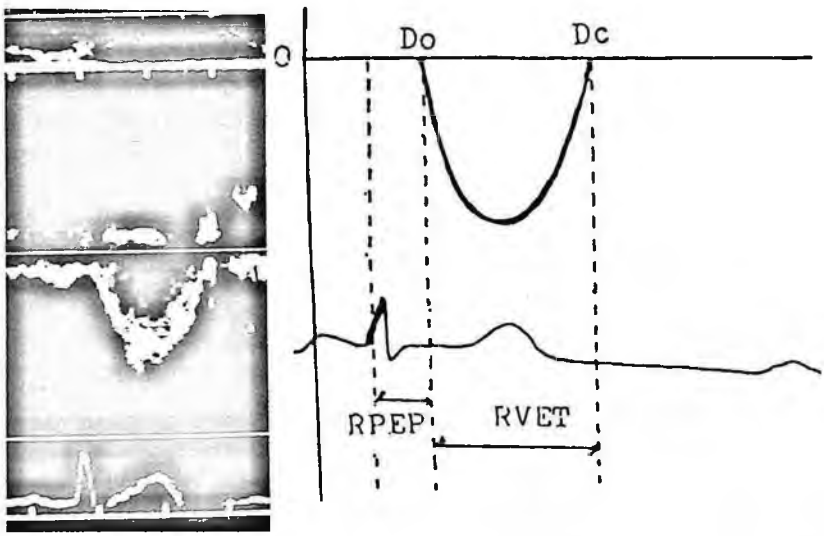

Fig. 18.10 Method of measurement of the systolic time interval by Doppler.

Table 18.1 Comparison of examination values of the RSTI in normal people and in patients with pulmonary heart disease.

	RPEP (ms)	RVET (ms)	RPEP/RVET
Normal (25 cases)	89 ± 15	338 ± 24	0.266 ± 0.017
With the disease (26 cases)	108 ± 21	274 ± 30	0.387 ± 0.26

18.5. ULTRASONIC DIAGNOSIS OF COMMON ANGIOCARDIOPATHY

18.5.1. Rheumatic Heart Valve Disease

18.5.1.1. *Echocardiogram Feature of Mitral Stenosis*

(a) M-mode echocardiogram displays motion curve of the anterior leaf of the mitral valve presenting "great wall-like" changes.

(b) The sectional image reveals thickening of the mitral valve, the apex of the valve is mostly nodular, echoes increase markedly, the opening of the valvular orifice is limited with an amplitude usually less than 2 cm. Owing to the limitation of motion by thickening, the apex of the valve is more marked than the body of the valve. Therefore, at diastole the apex and body of the valve present bow-like or right-angle-like curves.

At this point of time, the anterior valve and posterior valve move in the same direction. Some authors divide mitral stenosis according to the ultrasonographic features of the precardiac long axial section (Fig. 18.11):

Type-A: at diastole, the motion of the apex of the valve is limited, the middle leaf and root of the valve bulges bow-like in the direction of the interventricular septum. Most of them under this type are mild.

Type-B: at diastole, the motion of the apex and middle of the valve (body of valve) is limited, the root bulges in the direction of the interventricular septum. Most are moderate degrees of lesion.

Type-C: there is thickening of the entire mitral valve and the motion is limited. Most are serious types of mitral stenosis.

(c) Doppler ultrasound examination places the sampling container on or below the mitral orifice. It can examine high speed rushing flow frequency spectrum, and the

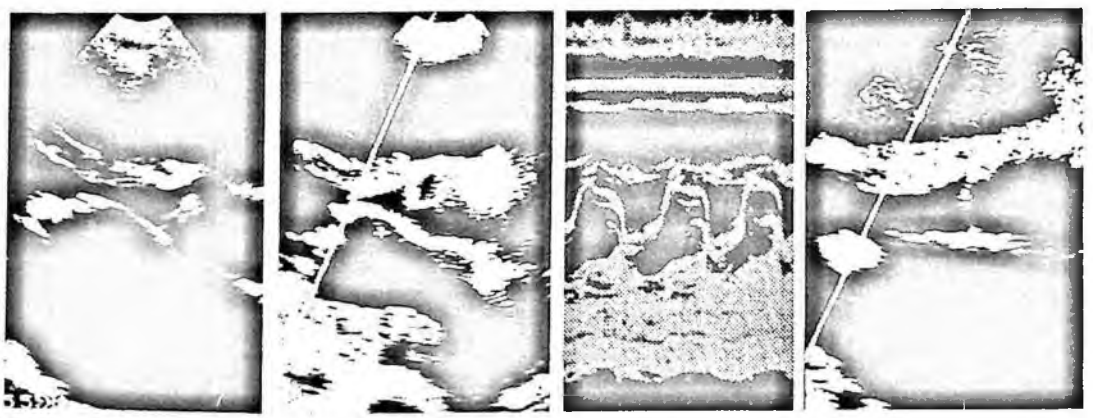

Fig. 18.11 Expression of different modes of ultrasound cardiogram of rheumatic heart mitral stenosis; (1) Type-A; (2) Type-B, complicated with formation of blood embolus (left atrium); (3) M-mode, presenting "great wall-like" change; and (4) Type-C.

normal frequency spectrum of the narrow double hump disappears. The speed of hump value rapidly increases, at diastole, the blood flow is replaced by a widened high speed rushing flow frequncy spectrum. Color Doppler Flow Imaging can display a blood flow band sprayed out from a stenosed orifice. Due to the high speed of flow, an aliasing sign often appears, namely the blue color appears in the centre of the red area, and there is often a yellow area induced by a rushing flow at the surrounding area.

In addition, the changes induced by the pathology of mitral stenosis are enlargement of the left atrium, dilatation of the pulmonary artery and enlargement of the left ventricle.

18.5.1.2. *Features of the Echocardiogram of Mitral Insufficiency*

(a) M-mode ultrasound displays an increasing speed of motion curve of the anterior leaf of the mitral valve.

(b) Sectional ultrasound reveals incomplete closing of the mitral orifice at systole. The mitral valvular ring may be enlarged. The valve is thickened, and the left atrium and left ventricle are enlarged.

(c) Doppler ultrasound can be used as a reliable method for the examination of mitral insufficiency. Place the sampling container on the valvular orifice or orifice at the side of the left atrium, it can examine widened filling rushing flow frequency spectrum during systole. According to the range of rushing flow frequency spectrum recorded in the left atrium, the degree of regurgitation can be determined. For instance, a serious degree of regurgitation is when the record can be obtained from the entire left atrium, a moderate degree is when the record can be obtained from half of the left atrium, and the mid degree of regurgitation is when the record can only be obtained at the orifice of the left atrium. Color Doppler Flow Imaging can display blue blood flow from the mitral orifice to the left atrium in total systole. In distinct mitral insufficiency, the red-blue mosaic image is usually obtained (Fig. 18.12).

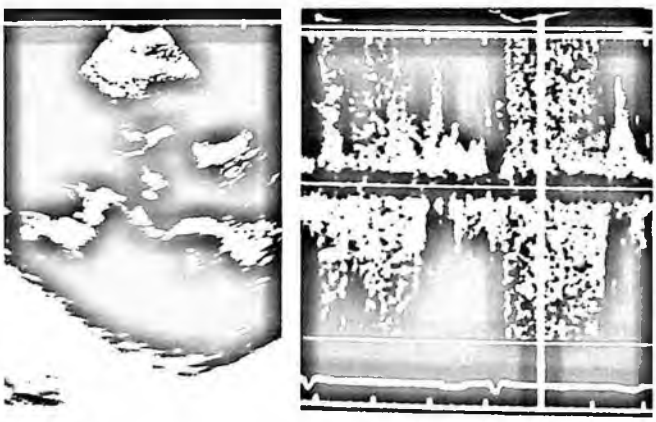

Fig. 18.12 Mitral stenosis complicated with incompetency marked systolic regurgitation frequency spectrum is examined at the side of the left atrium.

18.5.1.3. *Features of the Echocardiogram of Double Lesion of the Mitral Valve*

(a) M-mode ultrasound motion curve of the anterior leaf of the mitral valve presents "riding-horse-like" changes.
(b) Both sectional ultrasound and Doppler ultrasound have the features of mitral stenosis and incompetency.
(c) The left atrium is often markedly enlarged, there is hypertension of the pulmonary artery and marked dilatation.

18.5.1.4. *Features of the Echocardiogram of Aortic Stenosis*

(a) M-mode ultrasound shows that the amplitude of opening of the aortic orifice is small.
(b) Sectional ultrasound can show the thickening of the valve, enhancement of echo and markedly-limited motion. The amplitude of the opening of the orifice is smaller than 1.5 cm, and the wall of the left ventricle and interventricular spectrum may be thickened.
(c) By placing the Doppler sampling container on the orifice, one can record a marked increase in the width of the rushing flow frequency spectrum during systole. Color Doppler Flow Imaging can display a narrow, long stream of blue blood entering the root of the aorta and ejected from the stenosed orifice. Whether it is a coarse or fine ejection is related to the degree of stenosis. The more severe the stenosis, the finer the ejection, and often the sign of aliasing can be seen.

18.5.1.5. *Features of the Echocardiogram of Aortic Incompetency*

(a) The M-mode displays the motion curve of the aortic valve at the diastole as a double line or echoes of increasing thickness. The motion curve of the anterior leaf of the mitral valve at diastole may show fine tremors.
(b) Sectional ultrasound displays thickening of the aortic valve, it cannot be tightly closed during the moment, the width of the root of aorta increases and the left ventricle enlarges.
(c) The Doppler ultrasound examination usually uses the section on the five-chamber view on the apex or the long axial section on the apical left ventricle. The sampling container is placed on the outflow tract of the left ventricle. It can record the rushing flow frequency spectrum of the high speed filling width at diastole. Since the regurgitated flow presents a stirring motion, the frequency spectrum often presents a two-directional mode. If the rushing flow at diastole is limited to the inferior of the aortic valve or extends downward to the body of the anterior leaf of the mitral valve, it indicates a mild degree of regurgitation. If the rushing flow further extends to the apex of the anterior leaf of the mitral valve, it indicates a moderate degree of regurgitation. If the rushing flow is over the level of the mitral valve, up to the apex of the left ventricle, it indicates a severe degree of regurgitation. Color Doppler Flow Imaging can show a disorderly flow entering the outflow tract of the left ventricle from the aorta at diastole. In the apical five-chamber view, or in the long axial section of the para sternum, red blood flow regurgitating to the outflow tract of the left ventricle can be found. Mostly, signs of mosaic can also be seen (Fig. 18.13).

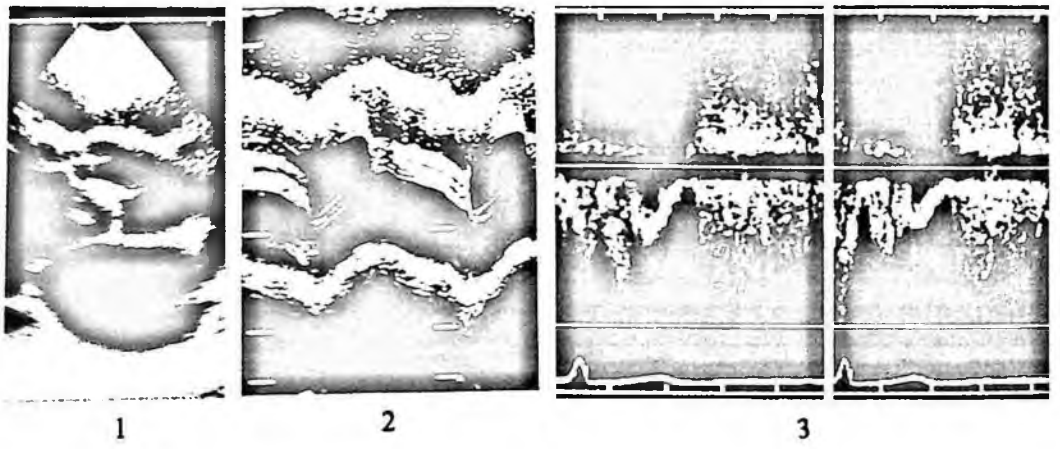

Fig. 18.13 Rheumatic heart aortic insufficiency: (1) Long axial section on the aorta. Aorta is markedly thickened; (2) M-mode displaying thickening of closing line at diastole; (3) Doppler examining regurgitation frequency spectrum at diastole at the aorta on the left side of the ventricle.

18.5.1.6. *Features of the Echocardiogram of Pulmonary Stenosis*

(a) M-mode ultrasound expresses the "a" wave in the motion curve of the pulmonary artery being deepened, mostly up to more than 6 mm.
(b) Sectional ultrasound reveals thickening of the pulmonary valve. The opening is limited, there may be signs of pulmonary dilatation after stenosis, and the right ventricle may enlarge.
(c) Doppler ultrasound examination takes the short axial section on the big blood vessel at the precardiac region. The sampling container is placed on the pulmonary orifice, the high speed rushing flow frequency spectrum at systole can be recorded.

18.5.2. Mitral Valve Prolapse Syndrome

This syndrome is caused by rheumatic heart valvular diseases, myocarditis, myocardiopathy and congenital heart diseases. Due to the pathological changes such as valvular tissue mucous degeneration, dilatation of the mitral ring, extension and thickening of the chordae tendinea, the too-long, ballon-like mitral valve tissues move to the left atrium and bulge towards left the atrium at systole. Usually, one point is taken at the juncture of the anterior leaf of the mitral valve and posterior wall of aorta, another point is taken at the ring portion of the posterior leaf of the mitral valve. The linked line of these two points is called the valve–ring linked line. Normally, the mitral valve will not exceed this line at systole, otherwise, it is known as mitral valve prolapse. The features of its echocardiogram are:

(a) At the long axial section of the parasternum or the section on the apical 4-chamber, one may find that the anterior leaf and/or posterior leaf of the mitral valve has move to the left atrium, over the valve–ring linked line. M-mode ultrasound may show the CD segment of the motion curve of the mitral valve presenting hammock-like changes.

It can also display the prolapse time phase at the whole systole, or at mid and late stage of the systole;

(b) Often dilatation of the left atrium can be detected;

(c) Doppler ultrasound examination can record regurgitation frequency spectrum at the side of the left atrium during systole (Fig. 18.14).

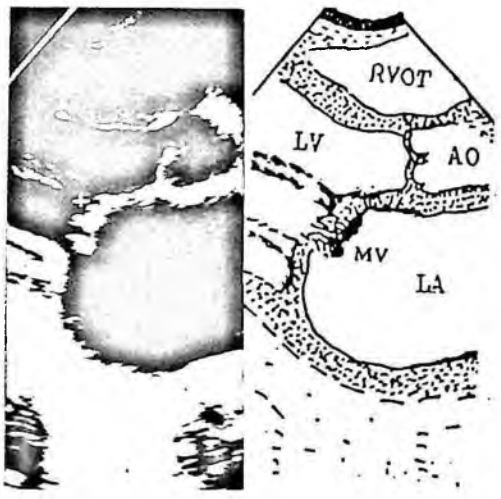

Fig. 18.14 Mitral valve prolapse. LV — left ventricle; LA — left atrium; MV — mitral valve; RVOT — outflow tract of the right ventricle; AO — aorta.

18.5.3. Laceration of the Chordae Tendinea

This disease may be caused by rheumatic heart diseases, infectious endocarditis, injury, mitral valve prolapse syndrome and myocardial infarction. Some of the causes may be unknown. The features of the echocardiogram are:

(a) Laceration of the chordae tendinea of the anterior leaf of the mitral valve
During systole, one may find "greater part of the anterior leaf of the mitral valve protruding into the left atrium, and the linkage of the valvular leaf with the chordae tendinea being discontinued. In the left ventricular cavity, one may sometimes find fragments of the chordae tendinea or valve in the left atrium. The mitral valve cannot be closed tightly at systole, and the valvular orifice is irregular. In the short axial section, one may find echoes of the chordae tendinea without connections to the valve motion.

(b) Laceration of the chordae tendinea of the posterior leaf of the mitral valve
This is commonly seen. At systole, the cusp of the posterior leaf swings into the left atrium. At diastol, the posterior and anterior leaf have asymmetrical motion, even the posterior leaf is still in the position of closing.

(c) Doppler ultrasound displays systolic regurgitation frequency spectrum at the side of the left atrium. Most of the cases are serious.

18.5.4. Myocardiopathy

There are two types of myocardiopathy, the primary and secondary myocardiopathy. In pathology, primary myocardiopathy is further divided into hypertrophy type, dilatation type and limitation type myocardiopathy.

18.5.4.1. *Hypertrophied Myocardiopathy*

It is divided into obstruction type and non-obstruction type, in accordance with whether there is obstruction of the outflow tract of the left ventricle, and it is further divided into several types according to the position:

(a) Thickening of localized myocardium presents asymmetrical changes, the thickness is mostly greater than 1.5 cm. Its ratio to the thickness of a normal myocardium is greater than 1.4–1.5;
(b) Contraction power of the localized myocardium involved in lesion is markedly decreased or lost, and the amplitude of the motion drops. The thickening property is practically lost at systole. The motion of a normal myocardium is compensatorily increased;
(c) Echoes of the myocardium involved in lesion are enhanced, the echogenic dots are disorderly, and the features of a normal myocardial pattern is lost;
(d) Types are divided according to position:
    (i) Common type: this type occurs when there is hypertrophy of the antero-superior part of the interventricular septum. The thickened base of the interventricular septum protrudes into the outflow tract of the left ventricle, causing stenosis of the outflow tract of the left ventricle. If the thickened portion is just below the aortic valve, it is also called the infra-aortic valve stenosis type. The left ventricular cavity loses its normal conditions. At systole, the motion of each wall is uneven, the motion is lost at the thickened part, the opposite myocardium usually has a compensatory increase in motion. This type is displayed by the long axial section of the left ventricle;
    (ii) Hypertrophy of the anterior lateral wall: the short axial section of the left ventricle displays thickening at the juncture of the anterior wall and external wall of the left ventricle, there is no thickening of the interventricular septum;
    (iii) Thickening of the posterior wall of the left ventricle: the long axial section of the left ventricle reveals that the posterior wall of the left ventricle is markedly increased, and that the low position of the interventricular septum is hypertrophied. Stenosis of the outflow tract of the left ventricle is not marked. M-mode reveals asymmetrical thickening of the posterior wall of the left ventricle. The short axial section of the mitral level of the left ventricle reveals thickening in the posterior part of the interventricular septum and the posterior wall of the left ventricle. At the level of the papilla muscle, the walls of the left ventricle show uniform thickening.
    (iv) Hypertrophy of the apical portion: the long axial section of the left ventricle reveals thickening in the myocardium of the interventricular septum near the apex of the heart. The cardiac cavity of the apex beomes smaller or obstructed. The short axial section of the left ventricle reveals thickening at the juncture of the posterior part

of the interventricular septum and at the posterior wall of the left ventricle. The cardiac cavity show asymmetrical contraction motions;

(v) Stenosis of the outflow tract of the right ventricle: the long axial section of the left ventricle reveals thickening in the antero-superior part of the interventricular septum, protruding into the outflow tract of the right ventricle. Deformity of the left ventricular cavity is not marked;

(vi) Generalized hypertrophy: every section reveals evenly uniform hypertrophy of the left ventricular wall. The amplitude of the myocardial contraction motion and the amplitude of the thickening are decreased.

(e) The types are divided according to whether there is obstruction of the outflow tract of the left ventricle.

(i) Obstruction type: the outflow tract of the left ventricle show marked stenosis. There is a closing phenomenon of the aortic valve at the mid-contraction stage, seen in the antero-superior hypertrophy of the interventricular septum, hypertrophy of the anterior wall, hypertrophy of the posterior wall of the left ventricle and generalized hypertrophy. The mitral valve moves forward at systole. M-mode ultrasound reveals lordotic motion of the CD segment (Fig. 18.15).

(ii) Non-obstruction type: the hypertrophied portion of the myocardium is far away from the outflow tract of the left ventricle, there is no phenomenon of marked stenosis of the outflow tract of the left ventricle and there is no phenomenon of closing of the aortic valve at mid systole.

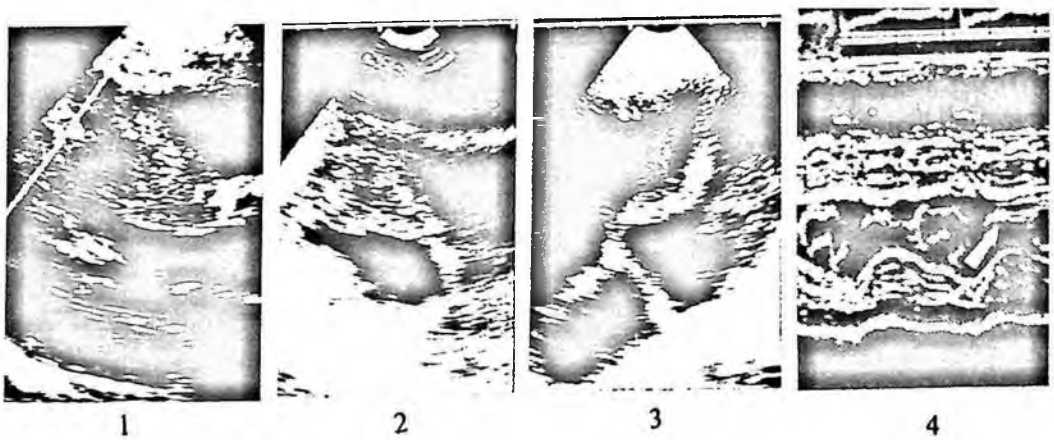

Fig. 18.15 Echocardiogram of hypertrophied myocardiopathy: (1) Generalized hypertropy; (2) Hypertrophy of the anterior wall; (3) Common type of hypertrophy of the myocardium; (4) Obstruction-type myocardiopathy. M-mode echocardiogram revealing lordotic motion of the CD segment.

18.5.4.2. *Dilatation Type Myocardiopathy*

(a) Every cavity of the heart is markedly dilated, particularly the left ventricle and left atrium, both sometimes present ball-like dilatation.

(b) The thickness of the interventricular septum and ventricular wall varies greatly. It may become thinner, normal, or increase a little, but the motion is markedly decreased.
(c) The amplitude of the motion of every valve is decreased and the closing time is markedly shortened. The M-mode ultrasound shows the motion curve of the mitral valve presenting the "diamond" type.
(d) There may be changes in the incomplete functioning of the papilla muscle and the phenomenon of incomplete closure of the atrioventricular valve due to dilation of the cardiac cavity. The Doppler ultrasound reveals the regurgitation frequency spetrum of the valvular orifice.
(e) Signs of hypertension of the pulmonary artery may appear.

18.5.4.3. *Limitation Type Myocardiopathy*

The main pathological change is fibrosis of the endocardium and myocardium. The expressions of the ultrasound cardiogram are:

(a) The apical four-chamber section of the short axial section of the aorta reveals a giant right atrium, as well as abnormality and loose closing of the tricuspid valve;
(b) The thickness of the endocardial echoes at the apical region of the left ventricle enhance and increase, the thickness of the cardiac wall is uneven, the cardiac cavity of the apex is blocked, causing deformity in the cardiac cavity and shortening of the longitudinal diameter. Mitral insufficiency occurs and there is mild or moderate enlargement of the left atrium;
(c) According to the different positions of the lesion, it may be divided into right heart type, left heart type and biventricular type, but it is mainly a lesion of the right heart.
(d) The pulmonary artery may be dilated (left heart type) or may become smaller (right heart type);
(e) In addition, there is dilatation of the superior vena cava, impairment in the pumping function of the heart, decrease in the cardiac output, and other changes.

18.5.5. Diseases of the Pericardium

18.5.5.1. *Percardial Effusion*

It is caused by inflammation, rheumatic fever and hemorrhage. The ultrasound changes are as follows:

(a) In the pericardial cavity, one may find echoless dark areas. In cases where there are small amounts of effusion (in the long axial section of the left ventricle, along the left border of the sternum), the echoless dark area will be found in the pericardial cavity from the posterior of the mitral ring to the posterior wall of the left ventricle, in the long axial section of the left ventricle, along the left border of the sternum. In cases with moderate amounts of effusion, the echoless dark area will also be found in the pericardial cavity anterior to the right ventricular wall. In cases with large amounts of effusion, the echoless dark area encloses the entire heart (except from the posterior to the left atrium) and the heart appears to be floating (Fig. 18.16).

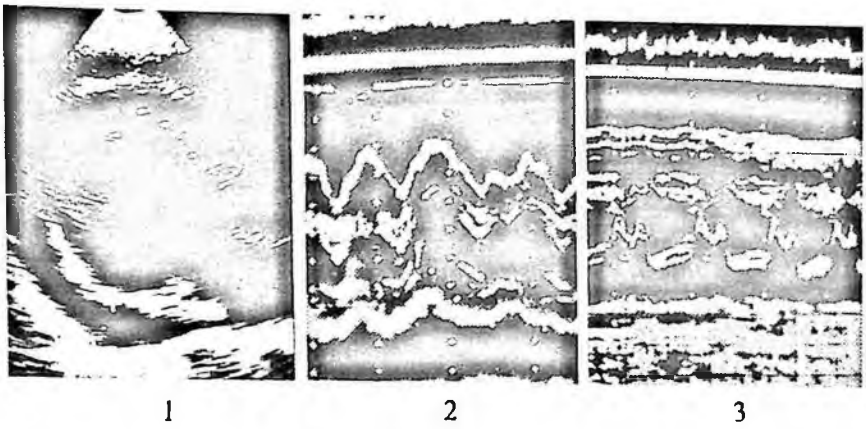

Fig. 18.16 Echocardiogram of pericardial effusion: (1) Section figure of pericardial effusion; (2) M-mode echocardiography of pericardial effusion; (3) Chronic pericarditis, pericardial effusion thickening of the epicardium.

(b) If there is pericardial tamponade, the internal calibre increases while the patient is inspiring and the internal calibre of the left ventricle is constricted;
(c) When the body position of the patient is changed and the echoless dark area of the apical region is increased, this indicates a capsulated effusion; if the echoless dark area is not increased, it indicates a non-capsulated effusion;
(d) When differenciating large amounts of pericardial effusion from the hydrothorax, the short axial section is mainly used to observe the relationship of the positions between the descending aorta and the posterior wall of the left ventricle. If the distance between the aorta and the left ventricular wall is increased, it indicates pericardial effusion. It is hydrothorax if the aorta is in close contact with the left ventricular wall;
(e) If the pericardial effusion is exudate, scattered floating echogenic dots or strip echoes can be found in the echoless dark area. If it is hemorrhagic, even and fine echogenic dots echo will be found.

18.5.5.2. *Chronic Thickening of the Pericardium (Constrictive Pericarditis)*

(a) There is thickening of the parietal pericardium and epicardium, marked enhancement of echoes and the increase in thickness is over 3 mm (Fig. 18.16.3).
(b) Sometimes, one may find low-level echo bands or echo of echogenic dots between the parietal pericardium and epicardium. The total thickness is over 3 mm.
(c) Sometimes, one may find localized calcification in the parietal pericardium and/or epicardium.

18.5.6. Infectious Endocarditis

This disease is often due to the invasion of bacteria to the endocardium. The growth and reproduction of the bacteria causes deposition of fibrinogen, white blood cells and platelets

on the valve, producing neoplasm or destroying the valve and forming ulcers. Even perforation or the formation of a flail valve may cause the breaking of the chordae tendinea, resulting in the mitral valve prolapse syndrome. Usually, more than one valve is involved. The mitral valve and aortic valve are most commonly seen. The features of the echocardiogram are as follows:

18.5.6.1. *Neoplasm of the Mitral Valve*

(a) M-mode ultrasound revealing motion curve of the mitral valve presents "flubby grass-like" change. The change in the amplitude of motion is not much.
(b) Sectional ultrasound reveals unequal sizes of enhanced hyperechogenic masses which may be round, oval or irregular shapes. They have a regular motion with the cardiac cycle, to and fro, between the left ventricle and left atrium.
(c) Doppler ultrasound may examine regurgitation frequency spectrum at the side of the left atrium, or stenotic high speed rushing flow frequency spectrum at the valvular orifice.

18.5.6.2. *Neoplasm of the Aortic Valve*

(a) M-mode ultrasound reveals the neoplasm presenting "flubby grass-line" changes with the motion of the valve.
(b) Sectional ultrasound reveals enhancement of the hyperechogenic mass attached on the aortic valve. Their forms vary and prolapse of the aortic valve may also be induced. At systole, the echo of neoplasm moves to the aortic cavity; at diastole, it may drop to the outflow tract of the left ventricle. Combined with the short axial section, the position of the valve where the neoplasm is attached can be revealed (Fig. 18.17).

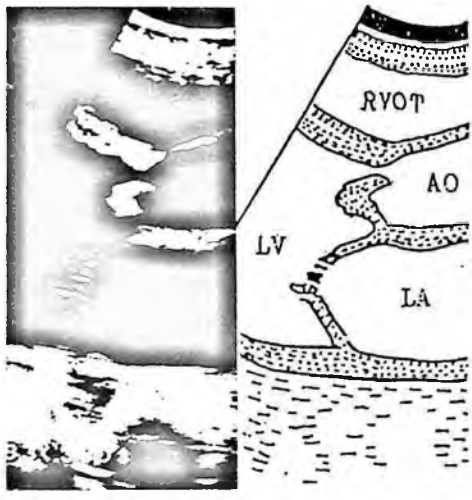

Fig. 18.17 Endocarditis, aortic valve and mitral valve neoplasm, aortic valve prolapse.

(c) Doppler ultrasound may detect the frequency spectrum of stenosis at systole, and regurgitation at diastole at the aortic orifice.

The chances of the tricuspid valve and pulmonary artery valve being involved are few. The features of ultrasonic change is similar to that of the neoplasm of the mitral valve or aortic valve.

18.5.7. Cardiac Tumor and Paracardiac Tumor

Cardiac tumors are divided into primary and metastatic tumors in which 80% of them are benign, primary cardiac tumors and of these 50% are myxoma. Left artial myxoma is commonly seen, and may be 4–5 times more than that in the right atrium. The majority of atrial myxoma has a pedicle attached to the interatrial septum, near the foramen of the ovale, 90% are solitary.

18.5.7.1. *Myxoma of the Left Atrium*

(a) In the left atrium one may find round, or elongated, oval hyperechogenic mass with enhancement of echoes following the cardiac cycle and moving in between left atrium and left ventricle. At systole, the tumor returns to the left atrial cavity; at diastole, the tumor reaches the mitral orifice or enters the left ventricle. Its position is related to the position where the pedicle is attached (Fig. 18.18).
(b) M-mode ultrasound presents "great wall-like" change at diastole in the anterior leaf of the mitral valve. At systole, mass-like or cloudy-like echoes are found in the left atrium;
(c) Doppler ultrasound places the sampling container on the mitral orifice to examine the high speed frequency spectrum at diastole.

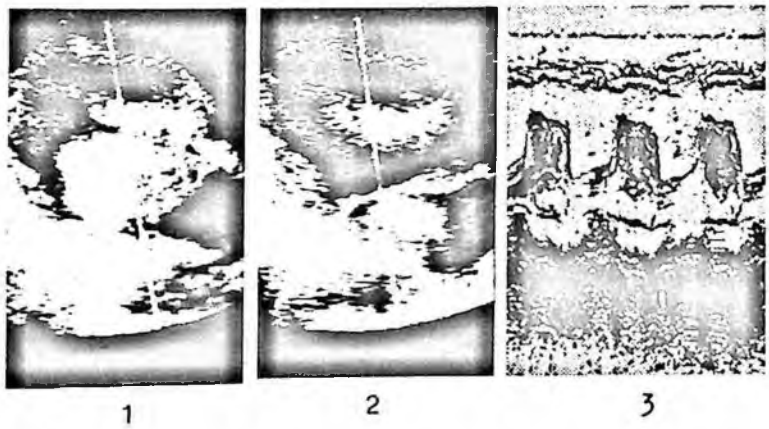

Fig. 18.18 Echocardiogram of myxoma of the left atrium: (1) Tumor entering the left ventricle at diastole; (2) Tumor returning to the left atrium; (3) M-mode ultrasound reveal cloudy echo from the posterior to anterior leaf of the mitral valve forming "great wall-like" change.

18.5.7.2. *Myxoma of the Right Atrium*

The echocardiogram is similar to that of myxoma of the left atrium. Abnormal echo mass of the tumor is detected in the right cardiac cavity, in the right atrium at systole. At diastole, the blood flow passes through the tricuspid orifice and reaches the right ventricle. If the tumor is too big, the degree of motion is less, and it cannot enter the right ventricle (Fig. 18.19).

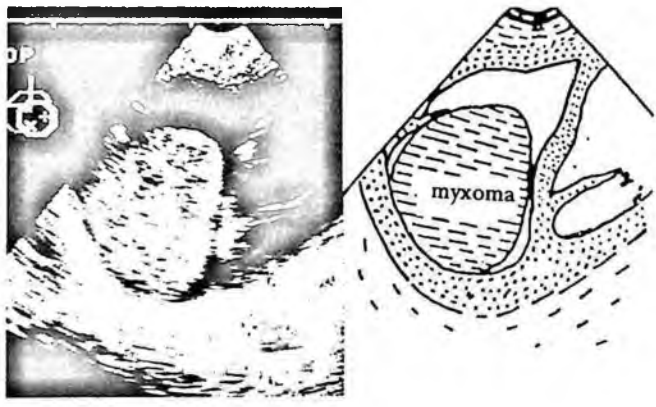

Fig. 18.19 Giant myxoma in the right atrium.

18.5.7.3. *Myxoma of the Ventricle*

Myxoma of the ventricle is rare. The ultrasonic expression is similar to that of myxoma in the atrium. Sectional ultrasound can reveal mass echoes of the tumor in the ventricle (left ventricle or right ventricle) moving similarly with the cardiac cycle. At diastole, it is in the ventricular cavity. At systole; the tumor mass protrudes into the outflow tract of the left ventricle or the outflow tract of the right ventricle.

18.5.7.4. *Differential Diagnosis of Tumor of the Heart*

A tumor of the heart is to be differentiated from an intracardiac false tumor, such as enlargement of the papilla muscle and intracardiac embolus. The papilla muscle has a definite form, it does not have the regularity of motion with the cardiac cycle. The position of the intracardiac blood emboli is mostly fixed, or it shifts with changes in the body position, similarly it does not have regularity with the cardiac cycle. Most of the blood emboli are in the form of long strips, some of them may be oval. The examination must be done in many sections and directions. Most are located in the left auricle, right auricle, the apex of the heart and lateral wall of the ventricle.

18.5.7.5. *Paracardiac Tumor*

Applying sectional ultrasound cardiogram, one may clearly diagnose the clinical phenomenon of displacement and oppression of the heart, and changes in the heart sounds

due to paracardiac tumor. The paracardiac tumor usually oppresses the base of the heart or the right auricle, resulting in clinical changes such as heart diseases (Fig. 18.20). The author used sectional ultrasound to diagnose 14 cases of paracardiac tumor, among them, five cases are lymphoma, the rest are thymoma, fibroma and teratoma.

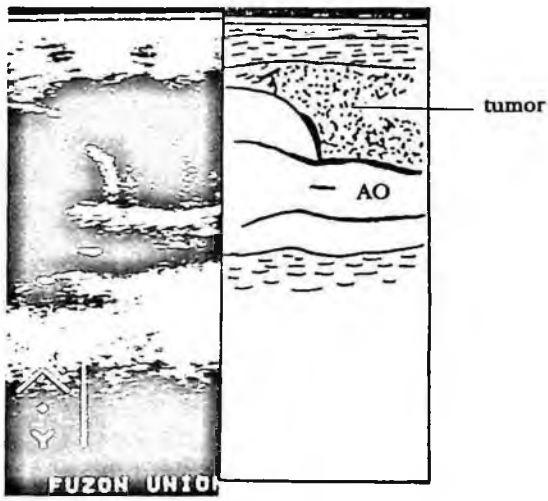

Fig. 18.20 Paracardiac tumor oppresses the right auricle and ascending aorta.

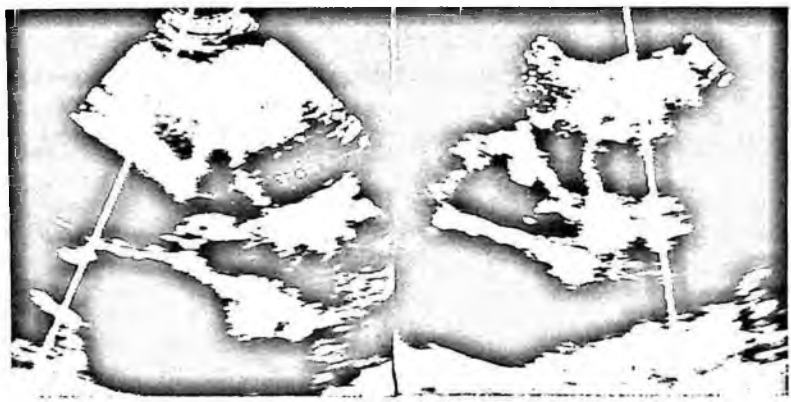

Fig. 18.21 Rupture of the sinus of valsalva. Left figure: Long axial section ruptured hole to outflow tract of the right ventricle. Right figure: Short axial section ruptured hole to outflow tract of the right ventricle below the pulmonary artery valve.

18.5.8. Rupture of the Sinus of Valsalva

The most commonly seen is the rupture of sinus tumor into the outflow tract of the right ventricle, but it is rarely seen rupturing into the right atrium. The ultrasound features are:

(a) In the long axial section of the precardiac region, by sectional ultrasound, one finds a prominence of the aorta root at the juncture of the interventricular septum and the root of the aorta. One may also find the ruptured hole facing the outflow tract of the right ventricle. In the short axial section of the big blood vessel one may find flames-spurting-like echoes at the base of heart. The right ventricle undergoes changes due to overloading (Fig. 18.21);
(b) In Doppler ultrasound, placing the sampling container on the hole of the rupture can be used to examine both the systolic and diastolic high speed rushing flow frequency spectrum simultaneously. Color Doppler Flow Imaging may show a colorful mosaic aliasing phenomenon;
(c) During the acoustic contrast examination, one can find a negative contrast area, having a rather high diagnostic specificity in a large amount of bubble acoustic shadow of the outflow tract of the right ventricle.

18.5.9. Dissecting Aneurysm

Dissecting aneurysm is divided into three types according to the pathological position:

Type I — The lesion often occurs at the ascending aorta, its range is not over the aortic arch, occupying about 60–70%;
Type II — The lesion is localized at the aortic arch;
Type III — Its range is from the root of the left subclavicular artery to the thoracic aorta, occupying about 20–30%.

Due to different pathological positions, the examination method is somewhat different. Usually the scanning method is used. The long axial and short axial section of the left ventricle is used to observe the changing conditions of the aorta.

(a) In the long axial section of the left ventricle, one may find an increase in the width of the root of the aorta, a separation of the endocardium and epicardium of the anterior wall and/or posterior wall of the aorta. A low-level echo dark area is in the middle, forming the double wall of the aorta. The thickness of the interseptal aortic wall is over 15 mm, and the dilatation of the root of the aorta is above 42 mm, indicating the existence of this disease.
(b) In the short axial cross-section of the aorta, one may find an increase in the width of the diameter of the cross-section of the aorta root. If the endocardium and epicardium of the aortic wall present an even separation, forming a circular echoless space, it is indicative of the dissecting aneurysm of the ascending aorta. If the separation is to one side of the endocardium, a decentered false cavity is formed (Fig. 18.22). If a similar phenomenon is seen in the descending aorta at the posterior side of the left atrium, it is diagnosed as the dissecting aneurysm of the descending aorta. If it happens at the cross-section of the aortic arch in the suprasternal fossa, it is called the dissecting aneurysm of the aortic arch.
(c) If the M-mode echocardiography reveals the anterior wall and/or posterior wall of the root of aorta presenting double walls, the distance is greater than 12 mm and the dilatation of the aorta is above 42 mm, it can also be diagnosed as dissecting aneurysm.

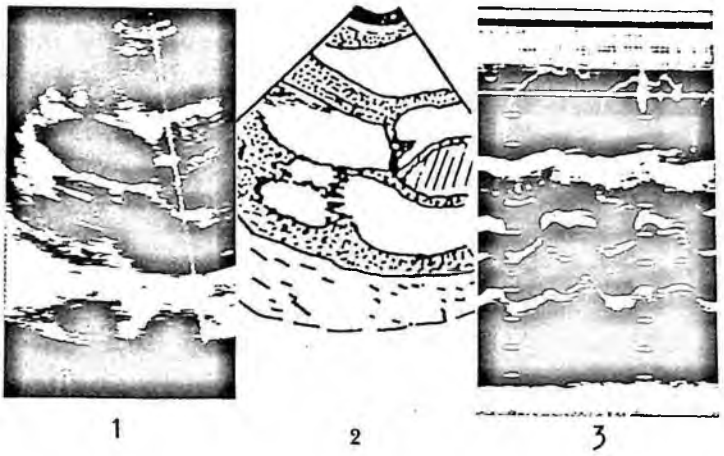

Fig. 18.22 Dissecting aneurysm: (1) and (2) Separation of the endocardium and epicardium at the posterior wall of the aorta; (3) M-mode ultrasound reveals the curve of the aortic valve deviated to anterior wall.

18.5.10. Congenital Heart Disease

In recent years, along with the development of ultrasound cardiogram, and particularly with the combined application of the M-mode ultrasound, B-mode sectional ultrasound, and Doppler ultrasound, there is a more accurate understanding of the anatomical structure and interspace relationship between the heart and big blood vessel. Therefore, this provides a more direct evidence in the diagnosis of congenital complicated malformations of the heart.

18.5.10.1. *Auricular Septal Defect*

It refers to the interruption to the continuity of the ostium secundum. Sectional ultrasound can detect thickening at the broken end and enhancement of echo, forming an "=" sign. It can also find the broken end floating to the right atrium (when shunted from left to right). Diagnosis is more reliable when using the infraxyphoid four-chamber view for the examination, as this avoids the formation of echo drop out due to the plane of sound beam being nearly parallel to the auricular septum when using the apical four-chamber view, hence resulting in the formation of a false positive (Fig. 18.23).

In Doppler ultrasound, the sampling container is placed on the right side of the auricular septum or at the place of defect. It can record the rushing flow frequency spectrum at the end of systole or at the early stage of diastole. The form of the frequency spectrum is determined by the ladder difference of the pressure between the left and right atriums. Usually, the frequency spectrum of the atrial defect presents three humps. The first hump is from the terminal stage of systole to early stage of diastole, the second hump is in the early stage of diastole and the third bump is in the terminal stage of diastole.

In addition, enlargement of the right atrium and right ventricle, and dilatation of the pulmonary artery can be found. Ostiun secundum atrial defect and patent foramen of ovale are difficult to differentiate.

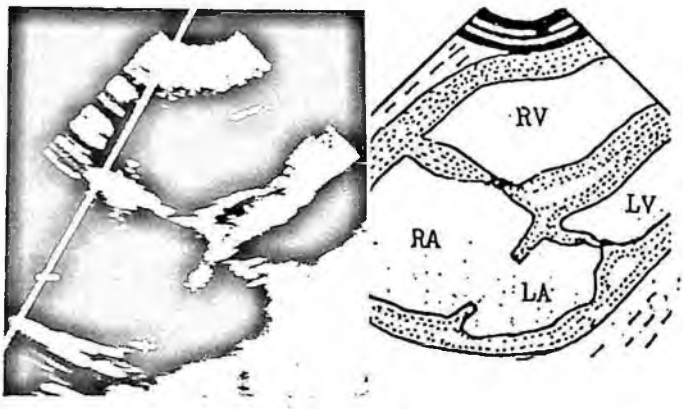

Fig. 18.23 Giant auricular septal defect (ostium secundum).

18.5.10.2. *Defect of the Endocardial Cushions*

It is divided into the partial type, namely the foramen primum auricular septal defect, and the complete type, namely, the foramen primum atrioventrical defect and the high-level interventricular defect.

(a) Sectional ultrasound finds that the lowest level of interruption of the auricular septal defect is the partial type defect of the intimal cushions. If low-level auricular septal defect comes with interruption of high-level interventricular septum, it indicates a complete defect of the intimal cushions.
(b) If complicated with the breaking of the mitral valve, the anterior leaf of the mitral valve presents a double layer strip-like echo. In the short axial section of the mitral orifice, the anterior leaf of the mitral valve is broken into two portions, like a suspension bridge.
(c) If complicated with solitary atrioventricular valve deformity, only a valve is displayed between two sides of the atrium and ventricle. The structure of this valve is formed by a big valvular leaf, each one from the left and right side.
(d) If complicated with malformation of the single atrium, in each cross-sectional image displaying the auricular septum, the auricular septal echo is absent (Fig. 18.24).
(e) Dilatation of the right atrium and right ventricle are commonly seen. If it is a complete type, dilatation of the left atrium and left ventricle are also seen. Most of the time the pulmonary artery increases in width.
(f) Doppler ultrasound similarly reveals the shunt frequency spectrum as an atrial defect. Direction of the shunt is dependent on the ladder difference in pressure between the atrium and ventricle of the left and right sides.

18.5.10.3. *Patent Ductus Arteriosus*

On the short axial section of the big blood vessel at the base of heart or on the long axial section of the aorta on the suprasternal fossa, patent dustus arteriosus can be seen between the pulmonary artery and descending aorta, accompanied by an increase in the width of the pulmonary artery and dilatation of the left atrium. M-mode ultrasound reveals the changes in the echocardiogram due to the overloading in the left ventricle. During the Doppler

ultrasound examination, the sampling container is placed on the middle portion of the trunk of the pulmonary artery or at its distal end. Marked diastole scattered rushing flow frequency spectrum and two stages of blood flow presenting double-directional change can be recorded (Fig. 18.25). If the sampling container is placed on the ductal orifice, a double stage positive direction rushing flow frequency spectrum will be recorded. If complicated with hypertension of the pulmonary artery, the frequency spectrum will only occupy a part of diastole. The higher the presure of the pulmonary artery, the shorter the time of shunt. Doppler Color Flow Imaging will show the abnormal blood flow facing the pulmonary valve, presenting images of red color alternating with yellow.

18.5.10.4. *Ventricular Septal Defect*

(a) M-mode ultrasound can display changes in increasing the severity of overloading of the left ventricle.

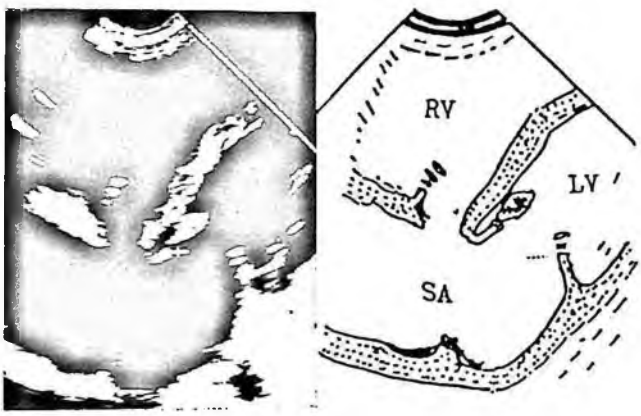

Fig. 18.24 Intimal cushions defect complicated with a single atrium.

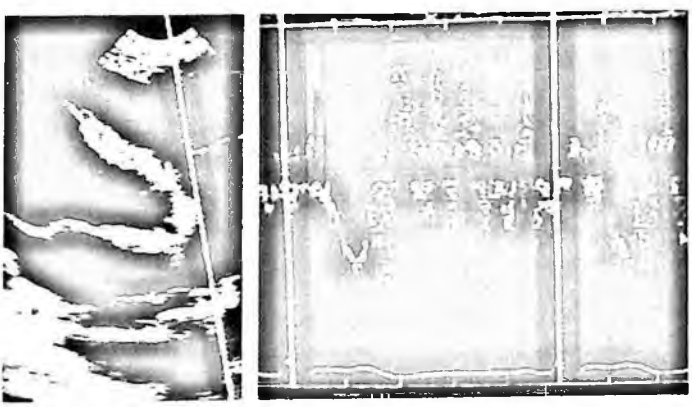

Fig. 18.25 Patent dustus arteriosus, marked diastole scattered rushing flow frequency spectrum detected in the trunk of the pulmonary artery.

(b) Sectional ultrasound can show the interruption to the continuity of the interventricular septum. The size of the defect varies. Small defects are not displayed clearly, they must be examined by many sections. The broken ends usually increase in coarseness, the echoes enhance forming an "=" sign (Fig. 18.26).

(c) During a Doppler ultrasound examination, the sampling container is moved from the membranous portion of the interventricular septum to the apex of the heart along the right ventricular face of the interventricular septum. High speed filling rushing flow frequency spectrum at systole can be recorded at the site of defect. If there is more than a moderate shunt, either left to right or vice versa, diastole or double stage rushing flow frequency spectrum will appear at the left ventricular border of the defect. If it is complicated with hypertension of the pulmonary artery, the ladder pressure difference between the left and right ventricles will be small. It is often difficult to record an accurate systole rushing flow frequency spectrum.

(d) The left ventricle enlarges and there is often dilation of the right ventricle, and an increase in the width of the pulmonary artery in the late stage. Muscular interventricular defects, defects near the apex of heart in particular, usually show false positive in the sectional image. At this point of time, it can often be detected by Color Doppler Examination.

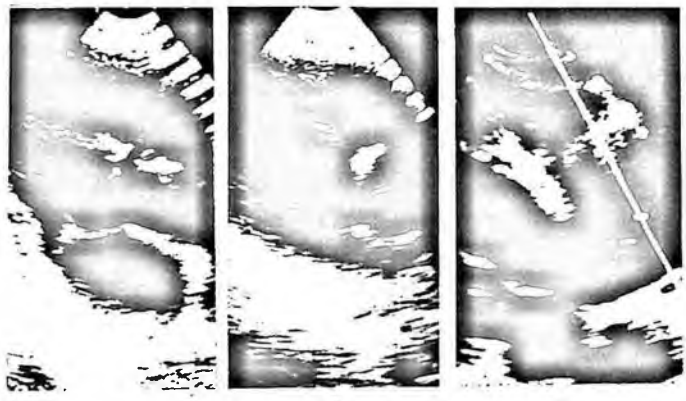

Fig. 18.26 Echocardiogram of interventricular septum defect: (1) Small defect at the membranous portion of the interventricular septum; (2) Inferior trunk type interventricular septum defect; (3) Enormous defect of the interventricular septum.

18.5.10.5. *Single Ventricle*

Both M-mode and B-mode sectional ultrasound cannot display echoes of the interventricular septum. From every sectional examination, only one ventricular cavity is displayed. If an acoustic contrast examination by the peripheral vein is done, it also displays one ventricular cavity only.

18.5.10.6. *Regurgitation of the Deformed Pulmonary Vein*

It is divided into partial type and the complete type. The partial type only reveals 1–3 pulmonary veins entering the left atrium in the apical four-chamber view. For the complete type, one cannot find a pulmonary vein entering the left atrium. The long axial section of the left ventricle may show a common trunk of the pulmonary vein posterior to the left atrium.

If there is existence of the left superior vena cava, the short axial section of the aorta from the suprasternal fossa can reveal the left superior vena cava. Sometimes, the long axial section of the left ventricle may show a dilated coronary sinus posterior to the left atrial wall.

18.5.10.7. *Congenital Supravalvular and Subvalvular Aortic Stenosis*

(a) Congenital aortic stenosis

This is often caused by the formation of two valves. The M-mode and B-mode sectional ultrasound reveal that the aortic valve echo is decentered, and the closing line is not at the center. The short axial section of the big blood vessel reveals that the valvular leaves are fused together, increasing in thickness and enhancing the echoes. The amplitude of the aortic opening becomes small. Doppler ultrasound examination can examine high speed blood flow frequency spectrum at the aortic valve orifice at systole.

(b) Subvalvular aortic stenosis

M-mode ultrasound reveals linear-like abnormal echoes at the outflow tract of the left ventricle. B-mode sectional ultrasound can show floating aortic subvalvular echoes at the outflow tract of the left ventricle, presenting linear floating with the cardiac cycle. The outflow tract of the left ventricle usually have different degrees of stenosis. If it is the muscular type, it is indicative of subvalvular aortic stenosis. The left ventricular face of the interventricular septum deviates to the outflow tract of the left ventricle. The anterior leaf of the mitral valve is commonly seen to protrude forward (Fig. 18.27).

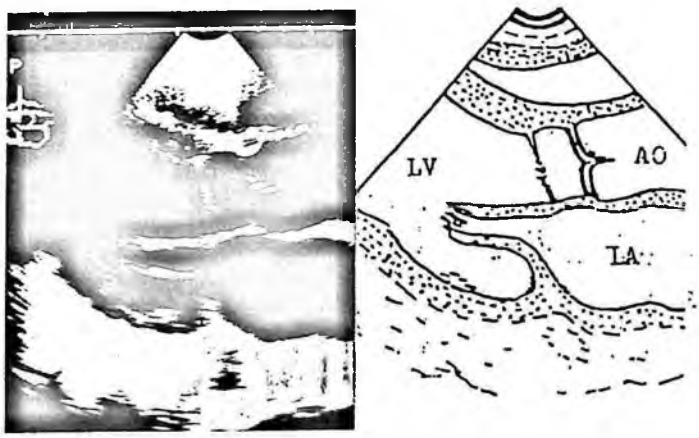

Fig. 18.27 Subvalvular aortic stenosis.

(c) Supravalvular aortic stenosis
Continuous scanning of the root of the aorta by M-mode ultrasound can detect marked stenosis at the supravalvular level of the aorta, and undergo the phenomenon of dilatation after stenosis. B-mode sectional imaging can detect the segment of supravalvular aortic stenosis, the enlargement of the left ventricle, an increase in the thickness of the ventricular wall, and an increase in the width of the outflow tract of the left ventricle. The Doppler sampling container is placed in a stenosed segment so that the high speed blood flow frequency spectrum can be recorded.

18.5.10.8. *Marfan's Syndrome*

M-mode and B-mode sectional imaging show that the internal calibre of the root of the aorta increases markedly in width (usually wider than 50 mm), and it is accompanied by mitral valve prolapse, relative aortic insufficiency, and an overloading of the left ventricle (Fig. 18.28).

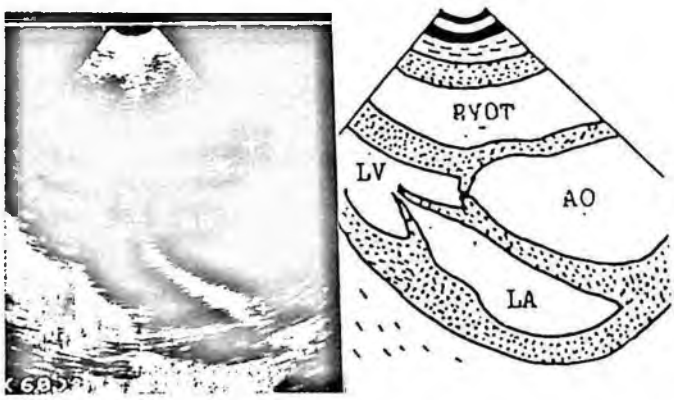

Fig. 18.28 Marfan's syndrome on the internal calibre of root of the aorta is enormous.

18.5.10.9. *Anomaly of the Downward Displacement of the Tricuspid Valve*

This is also called Ebstein's anomaly

(a) M-mode ultrasound reveals an increase in the amplitude of the tricupsid motion, the speed of closing the tricuspid at diastole becomes slow, presenting great-wall-like changes. The closing time of the tricuspid valve is 0.06 sec more than that of the mitral valve. There is marked enlargement of the right atrium.
(b) B-mode ultrasound reveals downward displacement of the triscuspid diaphragm valve and cuspis posterior valvulae tricuspidalis. The point of attachment is markedly displaced downward to the apical direction of the right ventricle. The distance from the point of attachment of the anterior leaf of the mitral valve to the left side of the interventricular septum is increased to a width greater than 1 cm (the normal distance between the two is 0.5–1.0 cm) (Fig. 18.29).

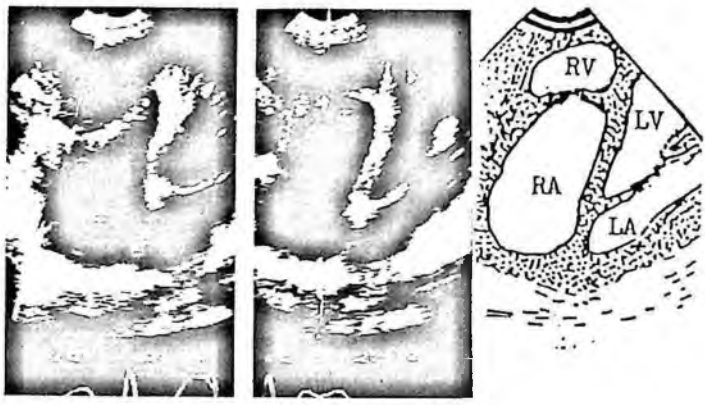

Fig. 18.29 Ebstein sign.

The right atrium may also be found to be markedly enlarged, it may also be joined with the right ventricular cavity above the malformed valve to become a big cardiac cavity, forming "right ventricle atriumized". The right ventricle below the malformed valve becomes the "functional right ventricle". Abnormal motion of the interventricular septum or atrial septal defect can often be detected.

18.5.10.10. *Atresia of the Tricuspid Valve*

Sectional ultrasound imaging cannot detect the echoes of the motion of the tricuspid valve with many directions and sections. Only at the place corresponding to the right atrioventricular valve can a thick echo band be displayed during systole and diastole. The right atrium and right ventricle are separated, and the anterior valve, diaphragm valve and posterior valve cannot be distinguish. When the Doppler sampling container is placed here, the blood flow frequency cannot be recorded at both diastole and systole. The outflow tract of the right ventricle is markedly stenosed, the right ventricular cavity shrinks, left ventricle enlarges and the amplitude of motion of the mitral valve is compensatorily increased. Often, it is complicated with other malformations such as auricular septal defect or interventricular septal defect.

18.5.10.11. *Tetralogy of Fallot*

(a) M-mode ultrasound reveals an enlargement of the right ventricle and the outflow tract of the right ventricle becomes narrow. By continuous scanning from the interventricular septum to the root of the aorta, one can find membranous defects in the interventricular septum and the forward displacement of the aorta riding over the interventricular septum.

(b) B-mode ultrasound imaging displays a forward displacement of the aorta, crossing the interventricular septum, and an interruption to the continuity of the interventricular septum and aorta. Stenosis of the outflow tract of the left ventricle and/or pulmonary valve stenosis, and/or stenosis of the trunk of the pulmonary artery occur. Also, there

is an increase in the thickness of the right ventricle wall and interventricular septum (Fig. 18.30).

(c) When the Doppler sampling container is placed on the site of defect, it can record the frequency spectrum of the shunt from the right to left.

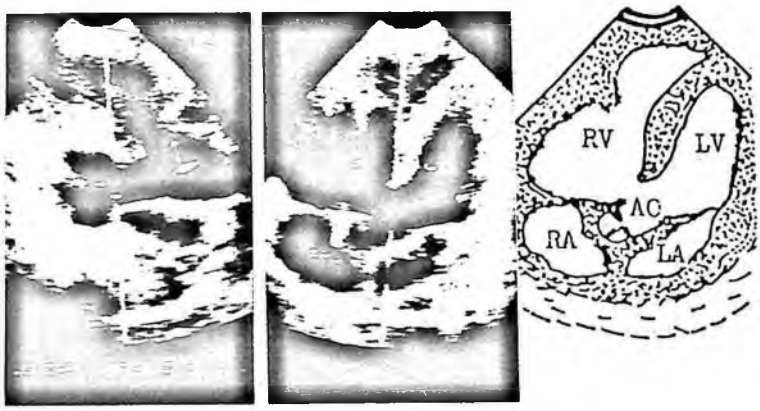

Fig. 18.30 Tetralogy of Fallot. Left figure is the long axial section, middle and right figures show the apical five-chamber view.

18.5.10.12. *Persistent Common Trunk of the Artery*

Sectional ultrasound shows that the trunk of the artery increases markedly in width and displaces forward in close contact with the thoracic wall. The trunk of the artery crosses the interventricular septum. The short axial section cannot display the trunk of the pulmonary artery. To differentiate this from Tetralogy of Fallot:

(a) In this disease, the outflow tract of the right ventricle is more stenosed;
(b) The left atrium is bigger (indicating more pulmonary blood);
(c) There may be abnormal valvular echoes in the trunk of the artery.

18.5.10.13. *Double Outlet of the Right Ventricle*

The main change is that there is no continuity between the posterior wall of the aorta and the anterior leaf of the mitral valve, within which the muscular tissues are mixed up, causing displacement of the aorta. Sectional ultrasound reveals the big artery is not sent out from the left ventricle. In between the posterior wall of the aorta and the anterior leaf of the mitral valve are the muscular tissues with strong echoes. The short axial section reveals the absence of the outflow tract of the right ventricle. By scanning from the left ventricle to the base of the heart, two branches of the big vessel are seen to be sent out from the interventricular septum. The short axial section of the two branches of big blood vessel reveal a side by side relationship, the position of the aorta is displaced to the right. In addition, ventricular defect and the enlargement of the right atrioventricular cavity can be seen.

18.5.10.14. *Trilogy of Fallot*

It is the auricular septum defect or patent foramen of ovale, stenosis of pulmonary artery and/or stenosis of the outflow tract of the right ventricle and hypertrophy of right ventricle. Sectional ultrasound reveals that there is an interruption to the continuity of the ostrium secundum of the auricular septum, stenosis of the outflow tract of the right ventricle and/or stenosis of the pulmonary artery, hypertrophy of the right ventricle, and dilatation of the right atrial and ventricular cavity. Doppler ultrasound may produce corresponding changes.

18.5.10.15. *Transposition of Big Blood Vessels*

Complete transposition of the big artery refers to a reverse in the positions of the aorta and common pulmonary artery. The main features of the ultrasound cardiogram are:

(a) The long axial section of the left ventricle, along the border of the sternum, reveals two great arteries parallel from the front to back and two ventricles. The aorta in front is completely derived from the morphological right ventricle, while the pulmonary artery behind is completely derived from the morphological left ventricle;
(b) The short axial section of the big artery at the base of the heart may show the aorta and pulmonary artery side by side, presenting two round images. If they are arranged right front and left posterior, this indicates the right transposition of the big artery; if they are arranged left front and right posterior, it is called left transposition. In the short axial image of the bifurcation of the pulmonary artery, one neither find the bifurcation of the pulmonary artery nor the left and right pulmonary arteries, but two round structures can be found (Fig. 18.31).
(c) The section of the outflow tract of the left ventricle on the subxiphoid and the axial section of the big artery show the outflow tract of the left ventricle connected to the bifurcated pulmonary artery, while the outflow tract of the right ventricle is connected to the aortic arch;

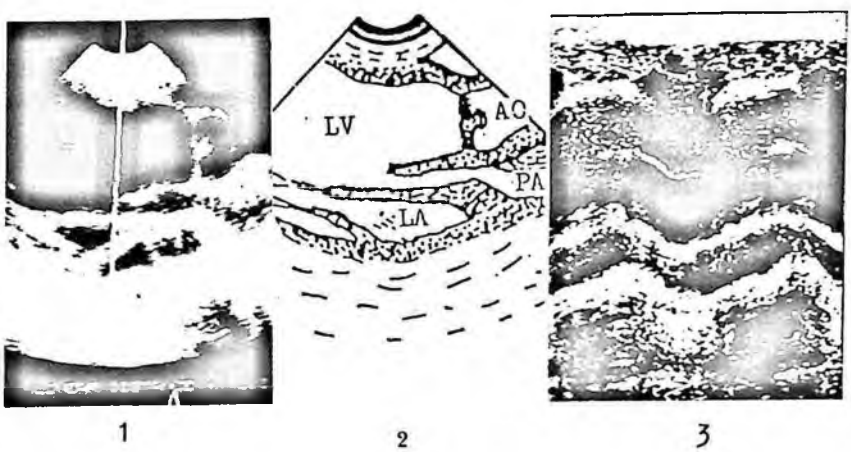

Fig. 18.31 Transposition of the big blood vessel: (1) and (2) Pulmonary artery is seen behind the aorta; (3) M-mode echocardiography revealing the pulmonary artery curve behind the aorta.

(d) This disease is usually complicated with other malformations such as interventricular septum defect or auricular septum defect.

18.5.10.16. *Aorta–Pulmonary Artery Septum Defect*

The short axial section at the base of the heart show that the trunk of the pulmonary artery is in communication with the aorta. The aorta and pulmonary artery are enlarged. At the place of defect, one can detect an abnormal Doppler frequency spectrum (Fig. 18.32).

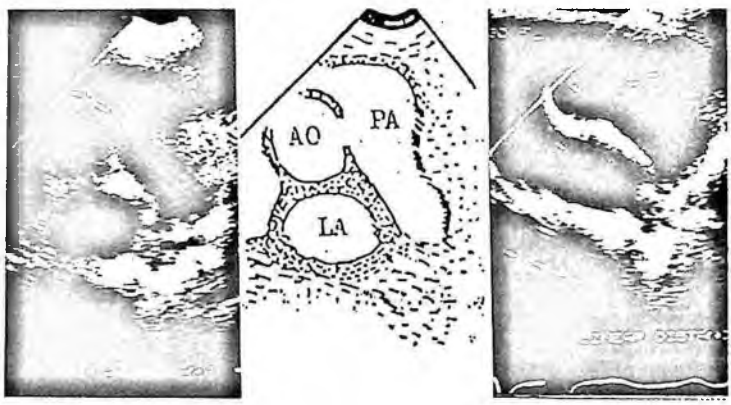

Fig. 18.32 Aorta-pulmonary artery septum defect.

18.5.10.17. *Cor Triatriatum*

Sectional ultrasound can reveal a diaphragm echo with the left atrium from every section. It can move along with the direction of the blood flow, and the defect can be seen causing the blood to flow into the intrinsic atrium from the accessory atrium (Fig. 18.33).

18.5.11. Expression of Echocardiogram of Coronary Heart Disease

18.5.11.1. *Chronic Coronary Heart Disease*

The echocardiogram changes of the disease still lack specific signs. Since the vascular cavity at the sites of the lesion become stenosed or blocked, a decrease in the blood supply to the myocardium results, causing degeneration, necrosis, fibrosis and compensatory hypertrophy of the myocardium. Insufficient supply of blood to the papilla muscle may appear as incomplete functioning of the papilla muscle. Therefore, the changes seen in the ultrasound cardiogram of chronic coronary heart disease are mainly dilatation of the heart, hypertrophy of myocardin, and decreased contraction of the interventricular septum and ventricular wall. Both M-mode and B-mode ultrasound may reveal a decrease in the segmental motion of the ventricular wall, disappearance of the motion and even abnormal motion (contradictory motion).

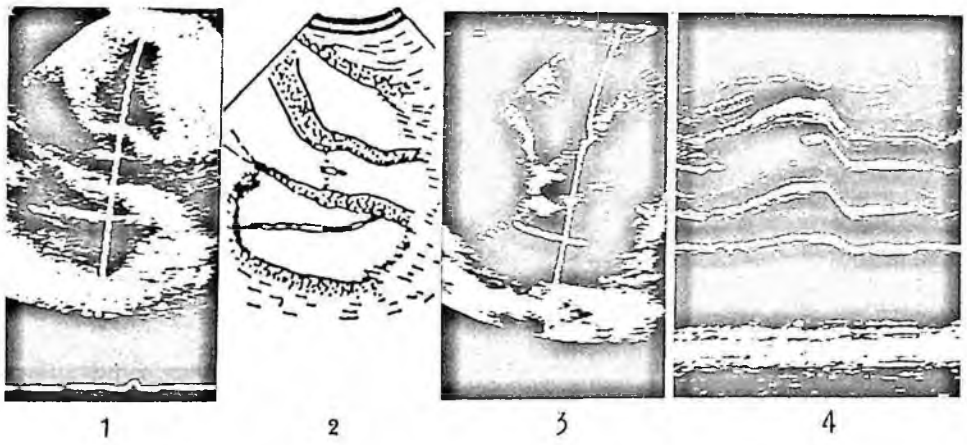

Fig. 18.33 Echocardiogram of cor triatriatum: (1) and (2) long axial section reveal a diaphragm echo in the left atrium; (3) four-chamber view reveal a diaphragm echo in the left atrium; (4) M-mode ultrasound reveal linear echo in the left atrium posterior to the aorta.

18.5.11.2. *Myocardial Infarction*

In acute myocardial infarction, the myocardial segmental motion is markedly decreased, appears to be lost, or is abnormal. In old myocardial infarction, ventricular wall segmental embarrassment is often presented as a decrease in motion. The form of the ventricle often changes. Since the lesion may have localized, mild-degree bulging, or since the scar of the original myocardial fibrosis lowers the elasticity causing the ventricle to dilate, the ventricle can lose its normal form.

18.5.11.3. *Complication of Myocardial Infarction*

(a) Ventricular aneurysm

Due to a wide range of myocardial infarction, in the course of healing, it is replaced by fibrotic scarring tissues, and so the elasticity is decreased. Due to the pressure from the ventricular cavity, bulging of the segmental ventricular wall appears. But the ventricular wall still perserves its integrity. Since the myocardium loses contraction force at this portion, contradictory motion will appear in the cardiac cycle, namely contraction motion during diastole and bulging motion during systole (Fig. 18.34). At this point of time, it should be differentiated from false ventricular aneurysm which is due to the rupture of the myocardium, causing the blood to fill the pericardium and forming localized bulging. Sectional ultrasound can reveal the site of rupture of the myocardium and the echoless dark area within aneurysm. Sometimes, one may find the existence of enhanced echoes of blood embolus within the echoless area.

(b) Attached wall embolus

Myocardial infarction involving the endocardium causes the endocardium to produce reactive inflammation, resulting in the formation of attached embolus in the ventricular cavity, which have different forms and unequal echo strength. For those with a long duration, the embolus may be organized or calcified, and the echo is markedly enhanced.

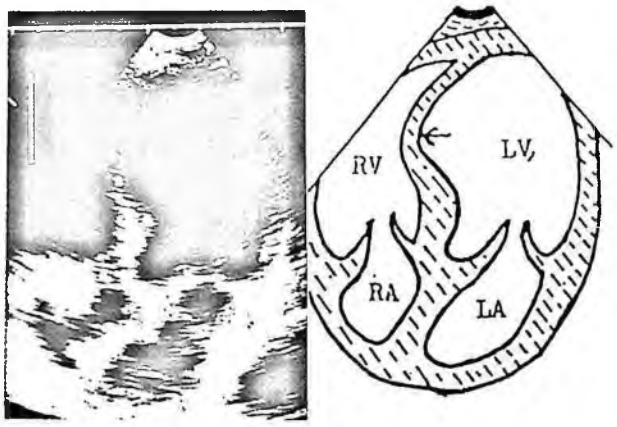

Fig. 18.34 Ventricular aneurysm in the left ventricle (shown by arrow).

Nowadays, sectional untrasound is used to observe the coronary artery. In the coronary artery image of a normal adult, the average value of the internal diameter of the left main trunk is 4.5 ± 0.9 mm, the echo of the endoderm is even and uniform. If atherosclerosis occurs in the coronary artery, then stenosis of the vascular cavity, uneven echo of the endocardium, and abnormal course of the blood vessel may be found. The pathological conditions of the coronary artery may be discovered directly. In recent years, ultrasound myocardial imaging, motion overload ultrasound cardiogram and ultrasound histology examination have been helpful in diagnosing and localizing coronary heart diseases.

18.5.12. Expression of the Echocardiogram of Pulmonary Heart Disease

An early pathological change of pulmonary heart disease is hypertension of the pulmonary artery. It is usually not easily diagnosed by clinical and ECG examinations, and can only be confirmed by measuring the pressure with a cardiac catheterization. The application of ultrasound cardiogram is helpful for the early diagnosis of pulmonary heart diseases.

18.5.12.1. *Changes in the Right Heart*

M-mode ultrasound and B-mode ultrasound can display the increase in the outflow of the right ventricle and in the thickness of the anterior wall of the right ventricle. Increasing the load of the right ventricle results in an increase in the amplitude of the tricuspid valve motion. Dilatation of the pulmonary artery is rather common. During a Doppler ultrasound examination, placing the sampling containers below the pulmonary artery can often record marked regurgitation frequency spectrum at diastole. It is related to the rising pressure of the pulmonary artery in pulmonary heart diseases and the dilatation of the pulmonary artery (Fig. 18.35).

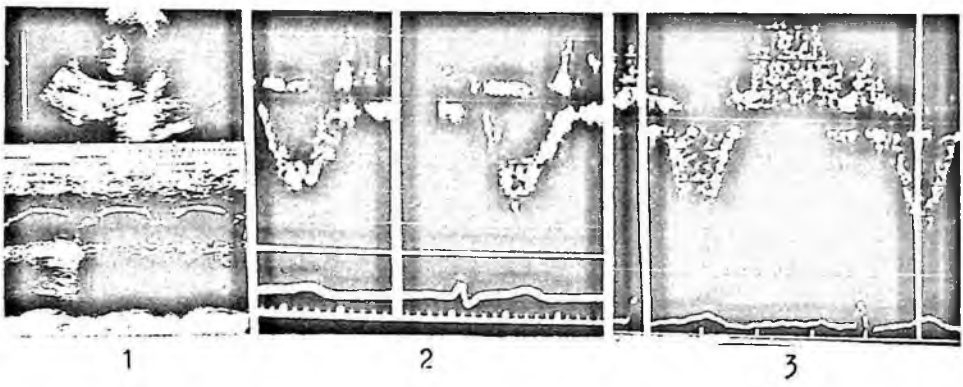

Fig. 18.35 Pulmonary heart disease accompanied by pulmonary artery hypertension: (1) Dilatation of the pulmonary artery, *a* wave disappears in the pulmonary curve; (2) Doppler frequency spectrum of a normal pulmonary valve orifice; (3) Hypertension of the pulmonary artery regurgitation frequency spectrum at diastole.

18.5.12.2. *Changes in the Left Heart*

The lack of oxygen for a long duration of time in pulmonary heart disease will cause atrophy and fibrosis of the myocardium. The left ventricle is usually not enlarged, rather it contracts. Many cases of pulmonary heart diseases express a "small heart". In quite a number of pulmonary heart diseases, due to the obstructive pulmonary disease, a decrease in the amount of pulmonary blood is seen. Therefore, the volume of the left atrium is markedly decreased, which is expressed in the constitution of the internal diameter of the left atrium. It is contrary to the enlargement of the outflow tract of the right ventricle. This is a more specfic change for pulmonary heart diseases. Once complicated with coronary heart disease, the left ventricle and left atrium are usually enlarged.

18.5.12.3. *Change in the Curve of Valve Motion*

The motion amplitude of the tricuspid valve increases, the motion amplitude of the mitral valve increases, *a* wave in the motion curve of the pulmonary valve disappears or the phenomenon of hypertension occurs, such as the closure of the pulmonary artery in the mid stage.

18.5.12.4. *Ultrasonic Examination Method of Pulmonary Heart Disease*

Due to the existence of emphysema, in most cases the patient should assume the left decubitus position. The probe is placed on the lower costal space or on the narrow sonolucent window at the left side of the xyphoid. Many patients have to be re-examined after breathing steadily or after asthma is controlled.

Chapter 19

Ultrasonic Imaging Diagnosis of Thoracopathy

Lin Liwu

As the intrapulmonic gas resists the transmission of ultrasound, it partly limits the application of ultrasound in the diagnosis of diseases of the lungs and chest, especially in deep pulmonary lesions. So the values of ultrasonic application in the chest has often been ignored in the past. In fact, when the amount of air in the lungs is changed by lung consolidation due to space-occupying lesion and/or a large amount of hydrops of the thoracic cavity, it becomes a good acoustic transmissible window, and the lesions can be displayed clearly. Ultrasonic examination remedies the defect of x-ray which does not display a large amount of hydrops in the thoracic cavity or the encapsulated fluid well. It helps to define the physical property and anatomic structure of the tumor and to understand the limits of damaged tissues around the tumor. As ultrasonic examination has the advantage of being non-radioactive, the movement of the diaphragm, the change processes of the lesion and hydrothorax can be observed many times. So ultrasonic imaging has clinical application values in the diagnosis of thoracopathy. It is used mostly in the following situations:

(a) Diagnosis of the tumors of the chest wall and lungs, especially the pleural tumors and the peripheral tumors of the lungs;
(b) Observing the situation and estimating the quantity of the hydrothorax;
(c) Judging the pleural adhesion or the pleural infiltration of the tumor by observing the lungs, the pleural lesions and their mobility when breathing;
(d) Discovering atelectasis and its degree, limits and internal situation, etc.;
(e) Diagnosing the space-occupying lesion of the mediastinum, including its region, appearance, property and its relationship with the heart;
(f) Performing percutaneous puncture to the tumor of the chest wall, the peripheral tumor of the lungs and the chest wall for cytological and histological examinations, and the peripheral tumor of the lung and the hydrothorax puncture drainage under the guidance of ultrasound.

19.1. GENERAL DESCRIPTION OF THE ANATOMY OF THE CHEST WALL, LUNGS AND MEDIASTINUM

19.1.1. Pleura

The pleura is divided into two layers — the visceral layer and the parietal layer. The visceral layer is the serous coat which covers the lungs and stretches into the interlobar fissure of the lungs. The parietal layer covers the inner side of the chest wall, the superior side of the diaphragm and the lateral sides of the mediastinum, they are called the costal pleura, the diaphragmatic pleura and the mediastinal pleura respectively. The visceral layer and the parietal layer transit correlatively at the roots of the lungs and form a latent hermetic lacuna called the pleural cavity. There is a little serous fluid in the cavity. The place where the costal pleura and the diaphragmatic pleura shift to form a deeper gap is called the phrenicocostal sinus (often called the costophrenic angle in the clinic). The hydrothorax is the first to appear in the sinus (Fig. 19.1).

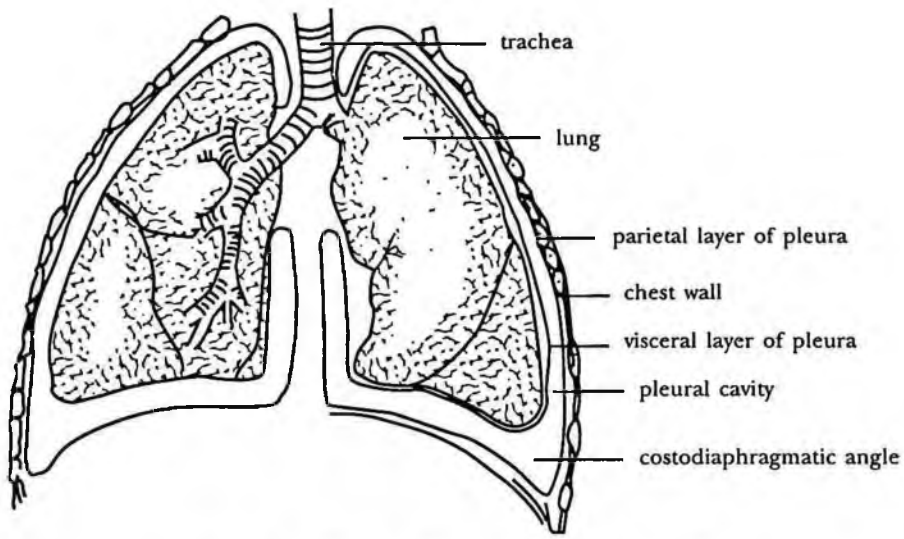

Fig. 19.1 Antomy of the chest wall and lungs.

19.1.2. Lungs

The lungs are in the thoracic cavity. The parenchyma of the lungs is soft like a sponge and elastic. The lungs contain a huge amount of gas. There is a small amount of fibrous connective tissues, plenty of capillary network, elastic fibers and macrophages between the pulmonary alveoli. They make up the pulmonary alveolus diaphragm.

The left lung is long and narrow. The right lung is thicker and shorter. Both lungs look like half of a circular cone. Each of them has a tip, a base, two sides and three edges. The top of the lung, called the apex of the lung, is round and blunt. It protrudes into the root of the neck through the superior aperture of the thorax, and is 2–3 cm higher than the inner

part of the clavicle. The inferior surface of the lung, called the base of lung or diaphragmatic surface, is hollow. The lateral surface of the lung, called the costal surface, is wide, round and convex, it is found close to the ribs and intercostal muscles. The medial surface of the lung, called the mediastinal surface of the lung, is close to the mediastinum. In the middle of the surface there is a clear hollow, called the hilus of lung, through which the bronchi, pulmonary vessels, lymphatic vessels and nerves go in and out of the pulmonary parenchyma. This structure, called the root of the lung, is surrounded by connective tissues and the pleura. The posterior margin of the lung is blunt and round. The anterior margin and inferior margin are sharper. There is a clear arc hollow called the cardiac incisure in the inferior part of the anterior margin of the left lung.

Both lungs are divided into lobes. The left lung is divided into two lobes by an oblique fissure (the interlobar fissure) from the posterior–superior to the anterior–inferior. Besides an oblique fissure in the right lung, there is a horizontal fissure (para-interlobar fissure) which is nearly horizontal and joins with the oblique fissure. Both fissures divide the right lung into the superior, middle and inferior lobes.

19.1.3. Mediastinum

All the organs and tissues between both lateral mediastinal pleuras are generally called the mediastinum. Its prezone is the sternum. The posterior limit is the thoracic segment of the spine. Both lateral limits are the mediastinal pleuras. Its superior limit is the superior orifices of the thorax, and the inferior limit is the diaphragm.

The mediastinum is divided into two parts, the superior mediastinum and the inferior mediastinum, by the plane from the sternal angle to the inferior margin of the fourth thoracic vertebral body. The inferior mediastinum is further divided into three parts. They are the anterior mediastinum between the sternum and the pericardium, the middle mediastinum where the heart and great vessels are located, and the posterior mediastinum between the pericardium and the thoracic vertebra.

The superior mediastinum is made up of the thymus gland (in the adult it is the remainder of the thymus gland), big blood vessels, trachea, esophagus, vagus nerves, thoracic duct, etc. The anterior mediastinum is made up of a few lymph nodes and loose connective tissues. The middle mediastinum is made up of the pericardium, heart, big blood vessels, bifurcation of the trachea, and the origin of the bronchus. The posterior mediastinum consists of the esophagus, thoracic aorta, umbilical veins, vagus nerves, thoracic sympathicus, thoracic duct, lymph nodes, etc.

19.2. ULTRASONIC EXAMINATION OF THE CHEST WALL, LUNGS AND MEDIASTINUM

19.2.1. Condition of the Apparatus

The linear real-time ultrasonic apparatus is the first choice. The manual compound scanning apparatus is also recommended. The different probes and frequencies should be chosen according to the different regions to be examined.

(a) The linear array probe, which has a wide field of vision, is adopted when the chest wall and the pulmonary lesions, which are connected with the pleura, are being examined.
(b) The section scanning probe or the convex array probe is adopted when the mediastinal lesions are being examined.
(c) When the diaphragm, apex of the lung, superior mediastinum through the suprasternal fossa or supraclavicular and big blood vessels are observed under the xiphoid process, the sector scanning probe or the convex array probe is used to scan fossa.

A high frequency probe, such as the 5-MHz probe, is recommended when the superficial structure, such as the pleura and the peripheral lung tissue, is observed. The 2.25–3.0-MHz probes are recommended when deep tissues, such as the hilus of the lung or the tissues in the posterior mediastinum, are observed. As the chest wall lesions and the peripheral lesions of lungs are always in the near field, the near field focus or the indirect examination method through a water bag, should be adopted. To increase the clarity, the gain should be suppressed when the pulmonary mass and hydrothorax are being examined.

19.2.2. The Patient's Preparation and Posture

There is no special preparation required by patients. The dorsal position and the intercostal examination are generally adopted. When the anterior and posterior parts of the middle axillary line and the mediastinum are examined, the lateral position is adopted. The sitting position and standing position can also be adopted to observe the costophrenic angle from the axilla and the back. The method of changing the patient's posture is often used to observe the mobility of the hydrothorax.

19.2.3. Method of Examination

19.2.3.1. *Intercostal Examination*

The probe is placed close against the intercostal space, sectorially sanning the space one by one from the upper to the lower side. The patient is asked to breathe deeply and slowly to avoid misdiagnosing the lesions beneath the costal ribs.

19.2.3.2. *Examination of Different Pathological Regions*

The examination area is emphasized on the pathological region, which is suggested by x-ray and clinical examinations. For example, the lesion of the apex of the lung could be examined from the supraclavicular fossa using the section scanning probe. The lesion at the base of the lung could be examined under the xiphoid process or the costal margin through the liver. Coronary scanning at the middle axillary line or back scanning can be used to observe the costophrenic angle and to examine the hydrothorax.

19.2.3.3. *Mediastinum Examination*

The lesions of the anterior mediastinum and middle mediastinum can be found if the sector scanning probe is adopted to scan from both the lateral sternum through the intercostal space from the upper to the lower side. The lesions of the superior mediastinum can be found if the suprasternal fossa examination is adopted. The lesions of the inferior mediastinum can be found if the method of scanning upwards under the xiphoid process and through the liver is adopted. In order to decrease the interference from pulmonary gas, the patients should be asked to expire and then hold their breath for a short while.

In brief, the limits of the chest wall, lungs and mediastinum are large. The ultrasonic areas of examination and the conditions are changeable. Therefore, section scanning, convex array scanning and linear array scanning should be used jointly depending on the different regions of the lesions.

19.3. SONOGRAMS OF THE NORMAL CHEST WALL, LUNGS AND MEDIASTINUM

When scanning the intercostal space, one can see an arched string-like hyperecho behind the muscular layer of the chest wall. It is the echo of the pleura, including the parietal pleura, a little fluid, which is physiological, and the visceral pleura. But there is no boundary between the two layers of pleura in the sonogram. Behind the echo of the pleura is the complete reflection hyperecho of the lung tissues.

Scanning upwards under the costal margin through the liver, one can see the smooth arched echoes of the diaphragmatic surface and diaphragmatic pleura. Behind them is the complete reflection echo of the lung tissues.

19.4. ULTRASONIC IMAGING DIAGNOSIS OF COMMON DISEASES OF THE CHEST WALL, LUNGS AND MEDIASTINUM

19.4.1. The Tumor of the Chest Wall

The tumor of the chest wall grows towards the thoracic cavity, even towards the lungs, and thus can be confused with the lung tumor. Its sonographic display is as follows:

(a) The appearance of the tumor is generally regular. The inner side shows low-level echoes and no strong echoes of gas in it.
(b) Behind the mass, the string-like echoes of the pleura can be seen. The mass does not move as the patient breathes.
(c) The strong echo of the lung tissues can be seen behind the mass and moves up and down as the patient breathes.
(d) There is an echo-free area between the two layers of pleura if there is little limited hydrothorax (Fig. 19.2).

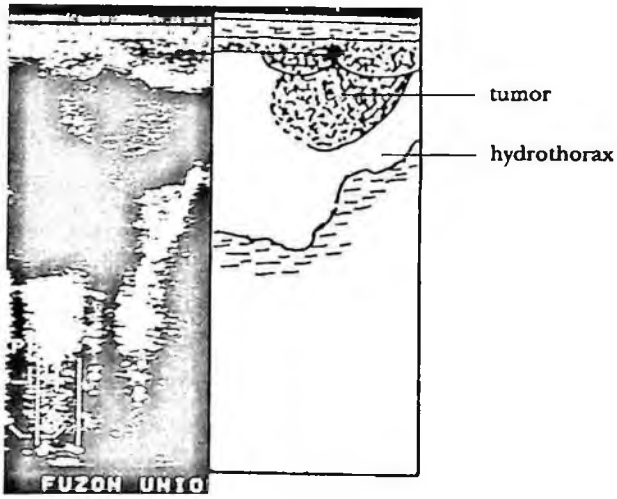

Fig. 19.2 The tumor of the chest wall.

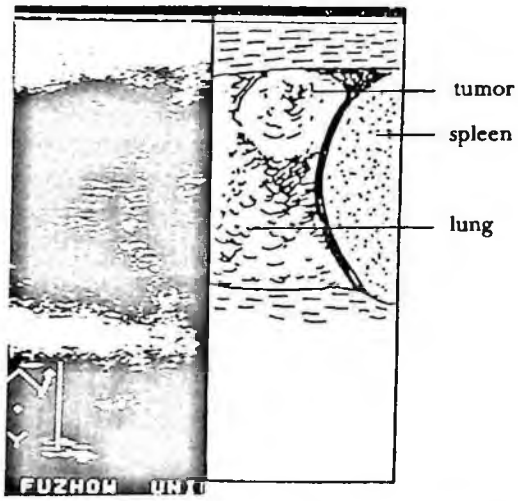

Fig. 19.3 Left pulmonary peripheral tumor.

19.4.2. The Peripheral Lung Tumor

The tumor growing near the hilus of lung is called the central type tumor of the lung or the tumor of the hilus of the lung. It is difficult to examine it by ultrasound. The tumor growing at the periphery of the lung, generating from the epithelium mucosa of small the bronchioles is called the peripheral type tumor or pheripheral nodular type tumor of the lung. The tumors are mostly nodose or ball-like in shape. There are no capsules. Their diameters are between 2–8 cm. They can mostly be displayed by ultrasound because their locations are near the chest wall. Their sonograms are a little different because of the differences of the growing area, the course of the disease, and the relationship with the chest wall.

(a) The tumor moves up and down with the patient's breathing. It moves simultaneously with the hyperecho lung tissues around it. If the peripheral lung tumor does not invade the pleura, it is sometimes displayed, (and sometimes not) with the patient's breathing. The thin echo of the pleura on the surface of the tumor is arched (Fig. 19.3).
(b) If the tumor invades the visceral pleura, a boundary and a small echoless area appears between the tumor and the chest wall. On both laterals of the tumor, the string-like echo of the visceral pleura is displayed. At the area of the tumor, the visceral pleura is hollow and blurred. The tumor still moves simultaneously with the hyperecho lung tissues around it when the patient breathes.
(c) If the tumor invades the chest wall, it is generally big. Its appearance is irregular. Its internal echo is heterogeneous. The tumor is just beneath the chest wall. The visceral pleura echo on both laterals of the tumor is uneven. Its echo in the area of the tumor is blurred or discontinuous. The movement of the tumor and the hyperecho lung tissues behind it is limited or has disappeared. If the tumor invades the ribs, the irregular hypoecho area in the invaded location is displayed.
(d) The sonogram of the lung tumor is clearer when it is complicated with hydrothorax and atelectasis than when there are no such complications. The echo of atelectasis is like that of the liver, which makes the boundary of the tumor in it very clear.

In brief, lung tumors are mostly malignant. Their sonograms show heterogeneous echo areas with irregular borderlines, and different degrees of acoustic attenuation at the posterior tumor borders. They are often complicated with hydrothorax and infiltration lesions of the pleura. The border of the pulmonary benign tumor is relatively regular. Its range is comparatively limited. It is less often complicated with hydrothorax. It was reported that the examinable rate of lung tumors by ultrasound was 70–80%. Ultrasonic and x-ray diagnosis can be mutally complementary when they are used in combination. This will raise the diagnostic level of the lung tumor.

19.4.3. The Sonogram of the Hydrothorax

It is accurate to diagnose the hydrothorax by ultrasound. A little hydrothorax can be displayed. Its location can be defined and the percutaneous hydrothorax puncture drainage can be conducted under the guidance of ultrasound. The sonogram of hydrothorax is as follows:

19.4.3.1. *Hydrothorax*

A triangular echoless area can be seen in the diaphragm when the coronal section scanning at the middle axillary line and the verticle scanning and transverse scanning at the posterior intercostal space along the scapular line are adopted. The diaphragm and the thorax form an acute angle. A long, strip-like echoless area behind the diaphgram of the liver can be seen when scanning under the costal margin through the liver is adopted. The appearance of the echoless area will change with changes in the body's posture (Figs. 19.4 and 19.5).

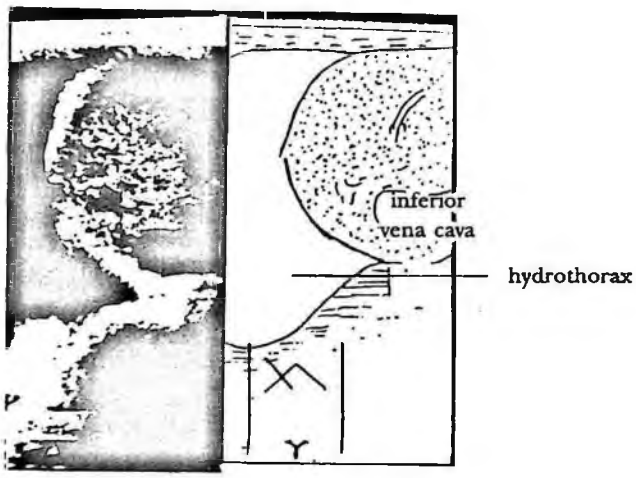

Fig. 19.4 A large quantity of right hydrothorax (intercostal scanning).

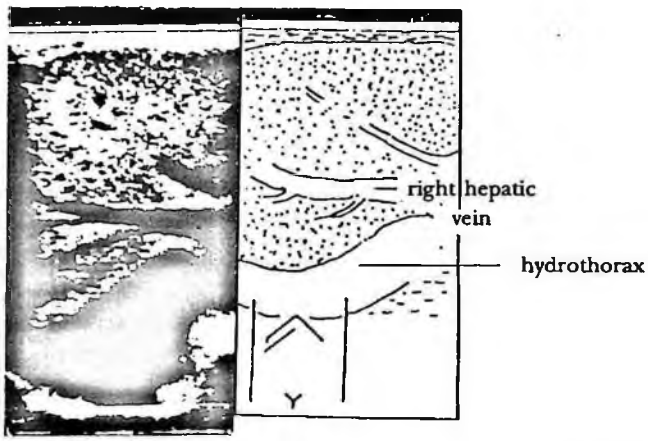

Fig. 19.5 A large quantity of right hydrothorax (scanning upwards under the right costal margin).

19.4.3.2. *Encapsulated Fluid*

It can occur at any site of the thoracic cavity, mostly in the sites of the oblique fissure and horizontal fissure. It can be examined at the intercostal spaces in both infrascapular regions, the middle axillary line near the axillary fossa, and the mammary gland region at the midclavicular line. The sonogram shows the irregular or elliptic echoless area. It appearance will not change when the posture changes. Localized thickening of the pleura can be seen, or lung consolidation may occur.

19.4.3.3. *Pyothorax*

The clinical course of the disease changes greatly. The patient has a high fever. The x-ray shows a stretch of shadows. The sonogram shows echogenic dots and rope-like echoes in the

fluid echo area. If pleural adhesion exists, echogenic dots and string-like echoes can be seen in the irregular fluid echo area (Fig. 19.6).

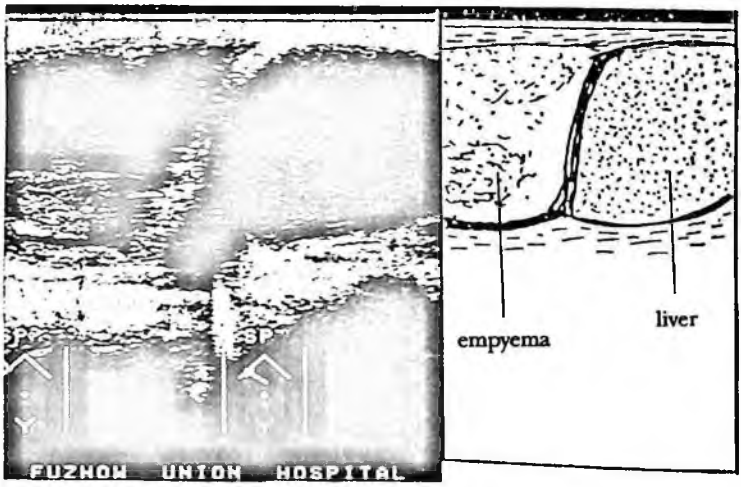

Fig. 19.6 The right pyothorax.

19.4.3.4. *Bloody Pleural Fluid*

The sonogram shows a fluid echo area with homogeneously scattered small echogenic dots in it. The echo of the pleura is clear. A lot of string-like echoes, which are in the sonograms of fibrinous structure, can sometimes be seen floating in the hydrothorax.

19.4.4. Atelectasis

When the lung tissues are compressed due to intrabronchial obstruction, the lesion of external pressure, or a large amount of hydrothorax, there is no gas in one or all parts of the lung, resulting in the lack of expansion or incomplete expansion of the lung. This is called atelectasis. The volume of the lung is markedly reduced. The sonogram clearly displays the inner structure of atelectasis.

The appearance of the sonogram is as follows:

(a) Sonogram showing atelectasis
The volume of the lobes of the lungs is markedly reduced. Its low-level echo is like that of the liver. Sections of the small trachea can be seen in the sonogram. The appearance of atrophic basis pulmonis presents an acute angle. Some cases of atelectasis are complicated with hydrothorax (Fig. 19.7).

(b) Partial pulmonary atelectasis
As there is still gas in some parts of the lungs, the echo level of the lung is higher than that of the liver. Strong echogenic dots can be seen in the sonogram of the lung. The volume of the lung tissues changes with the respiratory cycle. It is bigger during inspiration and the echo is stronger. It is smaller during expiration and the echo is

lower. If the causes of diseases such as intrabronchia obstruction and hydrothorax are eliminated, the atelectatic lung will gradually be filled with gas and the echo of the lung will be strengthened gradually.

(c) Atelectasis complicated with hydrothorax and intrathoracic tumor

If the complication is a tumor of the chest wall, an irregular mass projecting into the thoracic cavity from the chest wall can be seen. If the complication is a lung tumor, a mass can be seen in the atelectasic lung tissue. If the lung tumor is complicated with pleural metastasis, a great quantity of hydrothorax can be seen (Fig. 19.8). The pleura is markedly thickened. There are hypoecho nodular projections on the pleural surface.

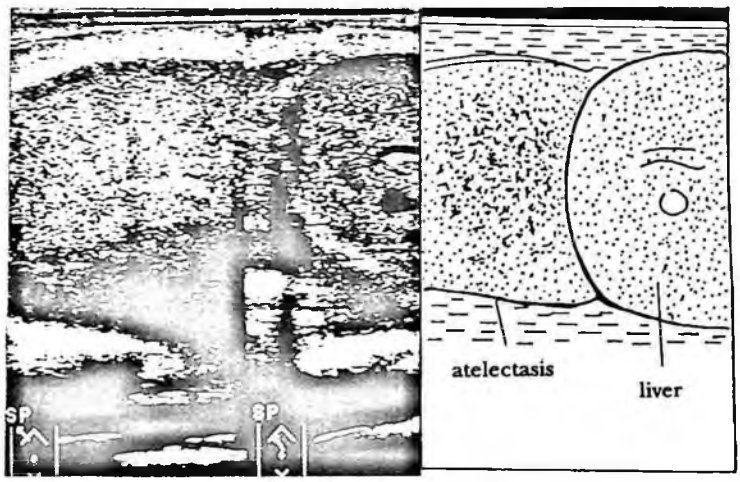

Fig. 19.7 The right atelectasis (caused by the tumor of the bronchus).

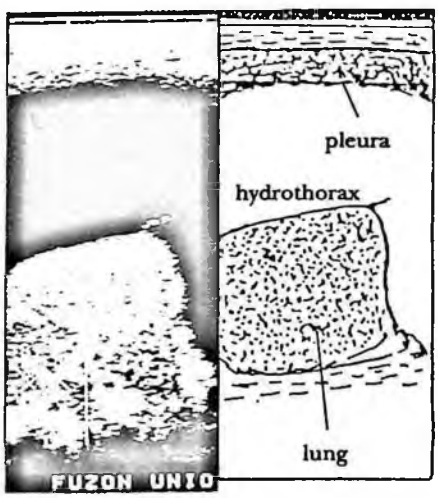

Fig. 19.8 Atelectasis caused by a large quantity of hydrothorax.

(d) Lung adherent with the pleura
The sonogram shows that the local lung tissues are adherent with the pleura. They move simultaneously when the patient breathes. The position of the adherent area will not change with a change in posture even if there is hydrothorax.

19.4.5. Pulmonary Abscess

The ultrasound has certain values in the diagnosis of pulmonary abscesses. The sonogram of acute and chronic pulmonary abscesses are different.

19.4.5.1. *The Sonogram of an Acute Pulonary Abscess*

An irregular hypoecho area can be seen in the lung tissues. It is full of echogenic dots. A hyperecho posterior margin can be seen. This is the sonogram of the inflammation period and early pulmonary abscess. As the disease develops, round echoless areas appear in the lungs. The border is clear. The echo of the posterior margin is strong. There are scattered, floating, flashing echogenic dots in the area. This is the sonogram of a intermediate and late pulmonary abscess.

19.4.5.2. *The Sonogram of a Chronic Pulmonary Abscess*

If the course of the disease is longer than 3–5 months, the wall of the vomica becomes thick and the echogenic dots in the vomica are in disorder. The lung tissues around the large abscess become compressed. The gas in the lung decreases and the lung is atelectatic (Fig. 19.9).

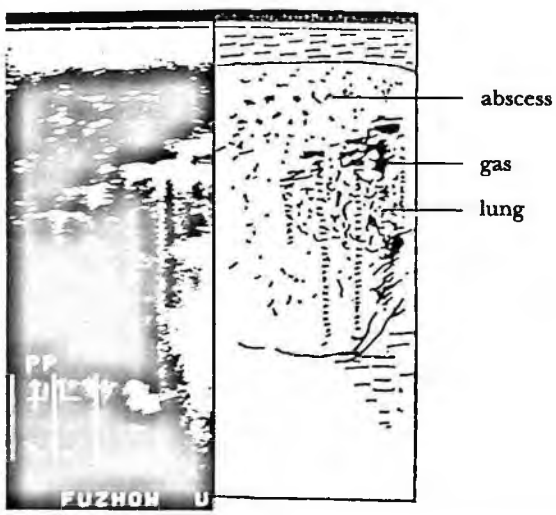

Fig. 19.9 Left pulmonary abscess. The lung tissue around it is compressed by atelectasis.

19.4.6. Mediastinal Tumor

According to some Chinese statistical materials, most mediastinal tumors are neurogenic tumors and after those are the teratomata and dermoid cysts. The incidence of thymonas comes after the above. Other materials report that most of the mediastinal tumors are thymonas and teratomata. Most of the tumors can be examined by ultrasound if different areas are scanned according to the locations of the superior and inferior mediastinum.

The appearance of the sonogram is as follows:

(a) According to the pathological characteristics, the appearance of the tumors is generally regular, elliptic or lobulated. Some of them are irregular. Their margins are clear and there are capsules around them.

(b) The inner echoes of the tumors are mostly homogeneous. If their properties are not the same, the echoes are different. For instance, the echo of teratoma is heterogeneous. There are echoes of separating strings or strong echoes of calcification. The walls of cystic teratoma and cystic thymoma are regular and clear. The lymphoma has more homogeneous low echoes or free echoes, and it has no capsule (Fig. 19.10).

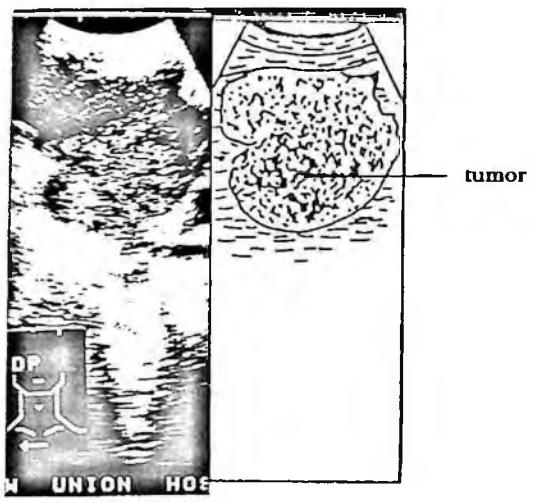

Fig. 19.10 Lymphoma of the superior mediastinum.

(c) The mediastinal tumor beside the heart often oppresses the auricle or big blood vessels, and cause images of pressure syndrome of the heart and vessels to appear (Fig. 19.11).

(d) If the tumor is not adherent to or it does not invade the tissues around it, it moves up and down within a narrow range along with the breathing of the person, it also moves opposite to the echo of the gas in the lungs. If the tumor is adherent to the tissues around it, its simultaneous movement with the lung and the surrounding blood vessels is limited.

In brief, the mediastinal tumors can be displayed by scanning from the lateral sternum through the intercostal spaces, from the suprasternal fossa, under the xiphoid process, or

through the intercostal spaces beside the thoracic vertebrae. Ultrasonic endoscope examination through the esophagus is more beneficial for the diagnosis of mediastimal tumors.

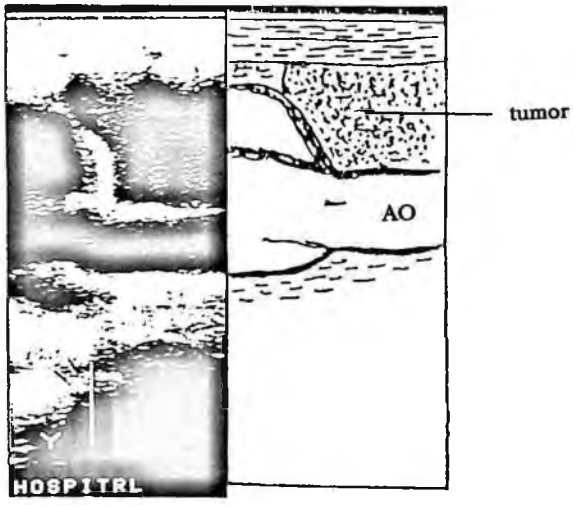

Fig. 19.11 Paracardiac tumor.

Part 5

Interventional Ultrasound

Chapter 20

Clinical Application of Interventional Ultrasound

Since the introduction of the B-mode puncture probe ultrasonically-guided puncture technique has rapidly developed. It can not only show the general anatomic structure in every section, the focal location, action of the examined organ and its relation with the tissues around, but also the route the puncture needle takes and the location of the tip of the needle, so that the puncture direction and depth can be strictly controlled. A target of 0.7 cm in diameter can be punctured accurately. Its success rate is much higher than "blind puncture" or "semi-blind pucture", it is also much safer than the latter. It has been widely used in clinic puncture contrast, fine needle cytological and histological examinations, aspiration and sclerosis treatment of cysts in the liver, kidneys or other organs, in drainage of abscesses, as well as puncture of the biliary tract to cure critical conditions of the biliary tract. It is accurate and rapid to carry out pericardiopuncture and thoracentesis under the guidance of ultrasound as damage of the heart and lung tissues can be avoided. Nowadays, it is widely used in the diagnosis and treatment of obstetrical diseases, such as amniocentesis, chorionic membrane biopsy, umbilical cord puncture through the abdominal wall to draw fetal blood, intrauterine fetal blood transfusion, intrauterine fetal celiac water-letting, aspiration of hydrocephalus, among others.

20.1. THE APPLICATION OF ULTRASONICALLY-GUIDED PUNCTURE IN CLINICAL DIAGNOSIS

20.1.1. Ultrasonically-Guided Percutaneous Transphepatic Cholagiography (US-PTC)

20.1.1.1. *Indication*

(a) Obstructive jaundice with unknown reasons.
(b) Dilation or stenosis of the intrahepatic duct is suspected.
(c) Carcinoma of the gall bladder is suspected.
(d) Disease of the biliary tract after cholecystectomy or calculi remaining in the biliary tract is suspected.

(e) Cancer of the biliary duct, including peri-ampullar carcinoma.
(f) Disease of the biliary tract without intrahepatic duct dilation.

20.1.1.2. *Preparations of the Apparatus*

(a) A B-mode ultrasonic imaging equipment with the special puncture probe must be prepared. An ordinary probe with fittings can also be used to make the puncture. The frequency of the puncture probe is 3–3.5 MHz.

The regulator in the puncture probe can be used to regulate the puncture needle to a suitable angle and then it is fixed so that the needle can puncture the target displayed in the screen accurately.

(b) A guided needle channel should be prepared. It is used to guarantee that the puncture hole in the probe matches the needle and the fine-needle can puncture straight. It has several sizes. Generally, the size used is the same size as that of the puncture needle, or one size larger.
(c) Another equipment that must be prepared is the puncture needle. Needles with size 21–22 stylets are generally used in the PTC operation.
(d) The ultrasonic conductivity gell which must be sterilized under high pressure is prepared for use.
(e) Other equipment used in PTC operation should also be prepared.
(f) The patient must take the bleeding and coagulation time test before the operation and take hemostatic medicine for two days.

20.1.1.3. *The Method of Operation*

(a) The puncture region and target must be confirmed. The dilated intrahepatic ducts, more than 5–7 mm in diameter, or the gall bladder can be selected as the puncture targets. The left intrahepatic duct is usually selected as the puncture target when all the biliary tracts dilate. The puncture point on the body surface is always selected at the intercostal space of the right anterior chest wall, below the right costal arch or the anterior abdominal wall, because it is always the shortest distance from the puncture point to the target.
(b) After sterilizing the skin and the application of local anaesthesia, the sterilized puncture probe is placed at the puncture point on the body surface and fixed. The puncture guiding line is determined. The puncture angle and the depth are measured. The angle is generally 5°–10°. The fixed equipment is the regulated according to the parameters that have been measured.
(c) The puncture needle is pierced into the abdominal wall through the guiding needle channel. The patient is asked to breathe normally. Advancing the needle slowly and observing the advancing process of the tip of the needle in the sonogram, a hyperecho spot is shown on the screen. Continue the advance of the needle and ask the patient to hold his breath for a short while. When the tip of the needle gets into the wall of the bile duct or the gall bladder, the needle must be pushed forth strenuously and punctured through the anterior wall, otherwise the wall would retreat to avoid the needle from puncturing into the bile duct or the gall bladder. When the tip of the

needle gets to the target, the patient is asked to breathe normally. Then the stylet is pulled out. If the bile flows out or is drawn out, it can be confirmed that the tip of the needle is in the target.

(d) The contrast medium, 20–30 ml of 30% meglucamine diatrizoate is infused into the bile duct or gall bladder under the observation of the x-ray television screen. The puncture needle is then drawn out. The patient's posture is changed and films are taken.

20.1.1.4. *Clinical Evaluation, Compilation and Prevention*

Common complications of PTC are hemobilia, intraperitoneal hemorrhage, bile leak, puncture of other organs and shock caused by high pressure in the biliary tract, etc. The US-PTC can basically avoid harming the liver vessels or neighbouring organs, for it can clearly show the structures of the liver and the biliary tract. Even the high pressure shock caused by the acute pressure rise in the biliary tract can be prevented by decreasing the testing infusion quantity and draining the bile. The main complication of US-PTC is bile leak. The preventive measures are as follows:

(a) Grasp the indications strictly.
(b) Use the fine-needle.
(c) As far as possible, puncture the gall bladder through the gall bladder bed.
(d) Avoid puncturing repeatly. Do not force a puncture through the wall of gall bladder when it is too hard to pierce.
(e) Drain the bile fully.
(f) Decrease the infusion quantity of the contrast medium as far as possible.
(g) It is preferable to make the contrast on the same day as the operation of cholecystectomy and to do it before the operation, except during an emergency.

20.1.2. Ultrasonically-Guided Percutaneous Pancreatic Ductography (US-PPD)

20.1.2.1. *Indication*

US-PPD plays a complementary role in diagnosing pancreatic lesions when ERCP is unsuitable for some patients. If the pancreatic duct is obstructed or the duodenum is deformed due to a tumor, cyst, pancreatic stone, or the outlet of papilla is too small due to inflammatory edema of the ampulla, the patient is unsuitable for ERCP examination. Yet the US-PPD can be conducted to detect if the distal pancreatic duct of the obstruction is dilated and to learn the situation of the site of obstruction and that of the pancreatic lesion. Also, pancreatic juice biochemisty, bacteriology and cytological examinations can be taken after the puncture of the pancreatic duct in order to comprehend the diagnostic materials.

20.1.2.2. *Pre-operative Preparations*

The apparatus and equipment are almost the same as that for US-PTC. The size 22–23 PTC puncture fine needle is used. The patient must undergo the serum prothrombin time,

platelet count, bleeding and coagulation time test. He must take the hemostatic medicine before the operation and fast in the morning of the operation.

20.1.2.3. *The Operation Method*

(a) The ultrasound examination is taken to study the location of the pancreatic lesion and to define the puncture target.
(b) After sterilizing the skin and the application of local anesthesia, the probe is fixed.
(c) The puncture needle is pierced into the abdominal wall through the guiding needle channel. The patient is asked to breathe normally. The sonogram must be closely observed during the operation.
(d) When pancreatic juice is drawn it means that the puncture is successful. The pancreatic juice can be sent for bacteriology and cytological examinations.
(e) The water-soluble contrast medium is infused slowly. After the x-ray films are taken, the contrast medium is drawn out and the needle is pulled out.
(f) After the operation, the patient must be nursed carefully and observed. The puncture area should be pressed for 12 hours in case of bleeding. The blood pressure and pulse must be measured regularly. The patient has to rest in bed, keep extremely quiet and fast on that day. He will also be given venous transfusion, and he must take the hemostatic medicine and antibiotics. A fall in blood pressure and severe abdominal pains indicate bleeding. It must be treated immediately. A surgical operation should be done if necessary.

20.1.2.4. *Clinical Evaluation and Complications*

US-PPD has a high rate of success. It is easier to succeed especially when the pancreatic duct dilates more than 4 mm. The sonogram of the segmental obstruction of the pancreatic duct can often be seen in a patient suffering from carcinoma of the head of the pancreas. The dilation of the pancreatic duct appears in the farther part of the obstruction.

Few complications may occur. Sometimes it is complicated with pancreatitis. The puncture is difficult if the diameter of the pancreatic duct is less than 3 mm or the patient suffers form chronic pancreatitis, with very hard pancreatic parenchyma.

20.1.3. Ultrasonically-Guided Percutaneous Pyelography.

20.1.3.1. *Indication*

The ultrasonically-guided percutaneous pyelography is mainly used on a patient suffering from urinary obstruction or hydronephrosis caused by calculi, tumor or stricture of the ureter, bladder or urethra. It can also be used on a patient whose phlebogram is unclear.

20.1.3.2. *Pre-operative Preparation*

(a) The patient's enema must be cleansed in order to get rid of the interference from stool and gas.

(b) The patient must take an iodine allergy test.
(c) The apparatus includes a real-time B-mode ultrasonic imaging equipment or a B-mode ultrasonic imaging equipment with a special puncture probe, a common pneumothorax puncture needle or a size 14 puncture needle, and 60% meglucamine diatrizoate.

20.1.3.3. *Operation Method*

The patient lies in the prone position and takes the B-mode ultrasound examination to study the location of the urinary lesion. The puncture site is fixed. If the hydronephrosis is marked, the cross-method can be taken to confirm the pucture spot on the body surface. If the hydronephrosis is slight, the special puncture probe could be used to confirm the puncture spot and to guide the needle. The puncture site is generally 2–4 cm lateral from the outer fringe of the greater psoas muscle. After sterilizing the skin and applying local anesthesia the probe is fixed. The puncture needle is pierced into the skin through the guiding needle channel, and advanced slowly. The sonogram must be closely observed during the operation. When the tip of the needle gets in the renal pelvis, the stylet is pulled out. If light yellow urine is drawn out, it means that the puncture has been successful. If the quantity of hydronephrosis is great, part of the urine must be drawn out before 20–40 ml of 60% meglucamine diatrizoate is infused into the renal pelvis, in case the contrast medium is dilute. The puncture needle is then pulled out and the patient is sent to take fluoroscopy and films.

20.1.3.4. *Clinical Evaluation*

The ultrasonically-guided percutaneous pyelegraphy has a high rate of success, and the patient does not suffer much. The development is clear. Almost all of the operations in the Union Hospital of Fujian Medical University are successful with only one puncture. It complements the deficiency of the antidromic pyelegraphy.

20.1.4. Ultrasonically-Guided Amniocentesis

In order to learn about the fetus's situation, a study of the amniotic fluid is necessary. The purpose of amniotic fluid examination during the 16th week of pregnancy is to investigate if the fetus has hereditary malformation and metabolic deficiency. It can be an accessory diagnostic method to help diagnose and treat blood group incompatibility after the 20th week of pregnancy. From the 34th week of pregnancy, the amniotic fluid examinations can indicate the fetal maturity.

20.1.4.1. *Indicators*

(a) Pregnant women older than 40 years of age.
(b) The pregnant woman's previous fetus is a mongoloid or she has a family history of mongolism.

(c) The pregnant woman has a family history of inborn error of metabolism, enzyme defect and autosomal abnormalities.
(d) The pregnant woman has previously borne a neonate with neural tube defects, or the value of serum alpha fetoprotein is markedly higher than that of a normal pregnant woman.
(e) It is suspected that maternal-fetal blood group incompatibility exists.
(f) The fetal maturity has to be determined after the 34th week of pregnancy.

20.1.4.2. *Operation Method*

The pregnant woman takes a B-mode ultrasound examination to determine the fetus' situation, the position of the fetus and the location of the placenta. She lies in the dorsal position after urination. The puncture spot is confirmed under the guidance of the B-mode ultrasound. It is generally near the fundus of the uterus during the first trimester of pregnancy. During the third trimester of pregnancy, it is mostly in the amniotic fluid vacancy where the fetal limbs and neck float about.

The principle of determining the picture spot is to evade the placenta and choose the deepest position of the amniotic fluid. After sterilizing the skin and applying local anesthesia, the puncture is conducted under the guidance of the ultrasound. If the puncture is carried out during the third trimester of pregnancy, the fetal body has to be pushed away from the puncture spot and fixed on the abdominal wall by the operator's hand. When the puncture needle is in the amniotic cavity, draw out 10–20 ml of amniotic fluid in the first trimester of pregnancy and 5–10 ml in the third trimester of pregnancy. The amniotic fluid drawn out into the syringe must not be infused into the amniotic cavity again. The pucture needle is then pulled out. The puncture spot must be pressed or binded by a pressure bandage. The pregnant woman has to be observed and must rest in bed for thirty minutes.

The amniotic fluid is sent to the laboratory to be cultured and all its components are determined. If maternal-fetal blood group incompatibility is suspected, the Rh negative pregnant woman should be injected with 1 ml (300 microgram) Rho (anti-D) immunoglobin to protect the parent substance.

20.1.4.3. *Clinical Evaluation*

Ultrasonically guided amniocentesis has several advantages. The method is simple and convenient. The number of puncture times is decreased. It is a safe operation and can avoid common complications which happen in blind punctures, such as bloody amniotic fluid, infection, amniotic embolism or fetal wound, etc. It causes little harm to the pregnant woman and fetus, and it is one of the major diagnostic methods used by the obstetrical department.

20.1.5. Ultrasonically-Guided Abdominal Umbilical Vein Puncture

The ultrasonically-guided abdominal umbilical vein puncture is a new technique of intrauterine fetal blood collection started since 1980. It has been reported both in China and

abroad. It has satisfactory effects and is much more advanced than other intrauterine fetal blood collection such as the fetal mirror. It is used in the clinic nowadays.

20.1.5.1. *Indication and Use*

(a) Prenatal diagnosis of some fetal diseases such as hemophilla, maternal-fetal blood group incompatibility, fetal thrombocytopenia, congenital cryptorrhea, rubella, fetal infection caused by cytomegalovirus and toxoplasma, congenital leulopenia, chronic granuloma, etc., can only be confirmed by the examination of pure fetal blood.
(b) Pure fetal blood can be used to promptly and accurately determine whether the fetus is suffering from any disease when the culture result of the amniotic fluid suggests some problems.
(c) It can be used to diagnose intrauterine asphyxia during the third trimester of pregnancy, because the pH of the fetal blood and the blood oxygen content are the most accurate basis for diagnosing intrauterine asphyxia.
(d) It can also be used to study pharmacodynamics during the gestational period and fetology.
(e) The operation can be used to treat fetal diseases directly, such as intrauterine fetal blood transfusion, blood platelet transfusion and directly injecting medicine into the fetal blood circulation to treat fetal diseases.

20.1.5.2. *Pre-operative Preparation*

The apparatus includes a real-time B-model ultrasonic imaging equipment with a special puncture probe, a size-12 ultrasonic puncture needle or a size-22 long needle. The probe and puncture needle are sterilized before usage.

Before the operation, the pregnant woman must take routine blood and urine examinations, bleeding and coagulation time test, and take hemostatic medicine for two days. She must urinate and take 10 mg of tranquilizer just before the operation.

20.1.5.3. *Operation Method*

The pregnant woman lies in the dorsal position, takes a routine examination with B-mode ultrasound to learn about and record the situations of the fetus and the attachment. The puncture spot is selected in the umbilical stalk, less than 2 cm from the placenta. As it is relatively fixed, it is the most ideal spot for the puncture. The sonogram of the umbilical stalk shows that the double equality sign of the umbilical cord connects closely with the placenta. The line echo of the fetal surface of the placenta is not continuous at this region. Yet the dark area opaca in the double equality sign of the umbilical cord and that in the placenta is continuous. The spot does not move when the pregnant woman changes her posture or when the abdominal wall is pushed. There are three different puncture routes according to the position of the placenta:

(a) Directly puncture into the umbilical vein through the placenta.

(b) Puncture into the umbilical vein through the placenta and amniotic cavity.
(c) Puncture into the umbilical vein through the amniotic cavity.

After the puncture spot is selected, it is sterilized, draped and anesthetised. The sterilized probe is fixed and placed at the spot with sterilized gel. The puncture angle and the depth are determined. The needle is punctured through the guiding needle channel. It must be advanced quickly through the abdominal wall, the uterine wall and placenta. When the tip of the needle gets to the wall of the umbilical vein, the needle must be pushed forth strenously and puncture the wall. When the tip of the needle gets into the umbilical vein, the stylet is pulled out. After drawing out an appropriate quantity (0.5–1.5 ml) of fetal blood, insert the stylet and pull out the needle. The puncture spot is pressed for a moment and the pregnant woman must be observed for 15 minutes by ultrasound in order to understand the situations of the fetal heart, fetal movement, and whether the puncture spot of the umbilical vein is oozing blood. If maternal–fetal blood group incompatibility is suspected, the Rh-negative pregnant woman should be injected with 1 ml Rho (anti-D) immunoglobulin to protect the parent substance. The pregnant woman should be re-examined by ultrasound 5–7 days later.

20.1.5.4. *Clinical Evaluation*

Ultrasonically-guided abdominal umbilical vein puncture is a secure, rapid and effective new method of obtaining fetal blood. After the 18th week of pregnancy the successful rate of puncturing only once can increase to 90.3–97%. No complications, such as miscarriage, dead fetus, infection and so on, could happen. It will not influence the fetal blood circulation and is of important significance in prenatal diagnosis as well as the study of orthogenics and fetology.

20.1.6. Ultrasonically-Guided Fine Needle Aspiration Cytological Examination

20.1.6.1. *Indication*

It is suitable for diagnosing occupying lesions of the liver, gall bladder, pancreas, spleen, kidneys, abdomen, stomach and intestine. But it is contraindicant to use it in patients with aneurysm, pheochromocytoma, hemangioma near the liver surface, and in a patient who has hemorrhagic trends as well as acute pancreatitis.

20.1.6.2. *Preparation of Equipment*

The high resolution real-time ultrasonic imaging equipment with the puncture probe must be prepared. The linear array scanner is mostly used in the puncture of abdominal organs and yet the sector scanner is mostly used in the puncture of the heart. They are all equiped with special puncture probes. The size 21–22 fine needles are usually used for the puncture of the liver and kidneys, the size 22–23 fine needles are used for the puncture of the pancreas. The external diameters of the size 21–23 fine needles are 0.8–0.6 mm and their internal diameters are 0.6–0.4 mm. The probe and the puncture needle are routinely sterilized before the puncture.

20.1.6.3. *The Method*

(a) The patient's preparation

The patient must eliminate or correct the hemorrhagic trend. The patient must examine the serum prothrombin time, and take the coagulation time test if he is suspected to have the hemorrhagic trend. Also he has to fast for 12 hours before the operation. If necessary the patient must be given enema or made to take carminative medicine for 2 days before the operation. He is told the purpose of the operation and asked to cooperate with the operator during the operation and not be too tensed up. A suitable sedative could be taken if necessary.

(b) The puncture method

The patient usually lies in the dorsal position. The puncture target and puncture line are determined. The puncture spot is then routinely sterilized and draped. Place the sterilized special probe there to confirm the accurate puncture spot again and measure the puncture depth. The puncture spot is anesthetised, and the probe angle is fixed. The fine puncture needle is pierced into the target or the lesion through the guiding needle channel. The process is monitored on the screen. The stylet is pulled out, connect a 10 ml syringe to the needle and draw. In the state of negative pressure, lift and stick the needle several times within the focus in a narrow range. Then relieve the negative pressure, pull out the needle, push the contents onto the glass slide rapidly and smear evenly. Fix the contents with 1:1 alchohol ether or 95% alcohol before they become dry. Look under the microscope after staining with HE staining or Giemsa staining. Sometimes, the guiding needle is pierced into the abdominal cavity first, then the puncture needle is pierced into the focus through the guiding needle, so that the puncture needle would not be flexed. This increases the success rate.

(c) The complications and points requiring attention

It is generally said that as long as the secure puncture line is selected, and the puncture depth and moving limits are well controlled, vital complications would not happen. Sometimes, a little complication such as a small hematoma of about 1–2 ml can happen. Yet it will be cured within a few days. In order to decrease or avoid the complications and raise the success rates of puncture and aspiration cytological examination, the following points must be noted during the operation:

(i) Observe the aseptic manipulation strictly.

(ii) Select the best puncture spot and route. The shortest distance is the best. Avoid hard tissues as far as possible. Ask the patient to cooperate with the operator, avoid coughing and breathe deeply during the operation.

(iii) The target must be clearly displayed. The tip of the needle must be clearly displayed before piercing and drawing; if it is not clearly shown, the angle of the probe must be corrected. Puncture must be accurate and prompt. Avoid letting the needle leave the target.

(iv) Avoid puncturing the large blood vessels around the lesion. The needle could be pierced through the stomach, intestine and bladder when they are vacant, but the drainage-tube cannot be retained.

(v) The puncture needle must pass a section of the normal liver before it punctures into the hepatic lesion or gall bladder. So the tumor near, or on, the liver surface must be carefully punctured or even contraindicant.

(vi) Avoid piercing and breaking the lung tissues.

(vii) Sample in the peripheral region if the center of the lesion is necrosed and liquidized.
(viii) Pay attention to the main points of the technique of sample smear, fixation and staining.

20.1.6.4. *Clinical Evaluation*

The confirmed diagnostic rate of ultrasonically-guided fine needle aspiration cytological examination of tumors, especially the abdominal malignant tumor, is higher than 80%, and that of the cystic lesion is 95–100%. It is an easy method with a high examinable rate and low false negative rate. The causes of false negative examination are as follows: The needle is not punctured into the target. The pathological cell has not been drawn out or the sample fixation and staining were not well operated. The usage of the method shortens the confirmed diagnostic time of diseases in the early clinical diagnosis. But it is difficult to make a confirmed classified diagnosis of the pathological histology, especially when diagnosing a benign parenchymatous lesion.

20.1.7. Ultrasonically-Guided Fine Needle Histological Examination

20.1.7.1. *Indication*

It is almost the same as the indication of ultrasonically-guided percutaneous fine needle aspiration cytological examination. It has the advantages of confirming the histological origin and pathological types as well as the exact pathological diagnosis of a benign tumor, making the histochemical stain and special stain, so as to raise the confirmed diagnostic rate.

20.1.7.2. *Equipment Preparation*

The real-time ultrasonic imaging equipment with the puncture probe must be prepared. The size 21–23 histological cutting fine needles are generally used. Their internal and external diameters are the same as those of the matching puncture fine needles for the cytological examination. Yet the structure of the tip of the needle is not the same. It has a sharp cutting-edge like the edge of a knife. The incline plane of the tip of the needle is less oblique than that of a common needle. The stylet is longer than the needle cavity. One of the ends of the stylet stretches out of the needle cavity, the other end is fixed on the needle plug. When the needle plug is pulled up, the stylet is simultaneously moved up, leaving an approximately 3-cm blank needle cavity at the tip of the needle for cutting tissues. Nowadays, multi-holed, histological biopsy needles are commonly adopted in China. It has the advantages of having an easy operation with a high success rate.

20.1.7.3. *Method of Operation*

The patient's preparation, the matters needing attention before and after the operation and the puncture procedure are similar as those for the ultrasonically-guided fine needle

aspiration cytological examination. Yet the sampling operation is different. In the ultrasonically-guided fine needle aspiration cytological examination, the puncture needle must be pierced into the tumor or the lesion. Connect the syringe with the needle and draw it to form a negative pressure, then lift and sting the needle several times within the focus in a narrow range to draw the fragmentary histiocyte. However, in ultrasonically-guided fine needle histological examination, the puncture needle with the stylet is pierced into the margin of the tumor or the focus. Then draw the needle plug to lift the stylet in order to reveal the cutting-edge of the tip of the needle, leaving an approximate 3-cm blank needle cavity. Push the needle into the tumor or the focus, and rotate the needle to cut the tissue, or pierce into the tumor and rotate at the same time, draw out the needle, then put the tip of the needle onto to a small piece of sterilized paper. Untie the key of the needle plug, move the needle straight and push the piece of tissue onto the paper. Avoid curling or breaking the piece of tissue. Put the paper in a neutral buffer formalin liquid for 4 hours to fix the sample, cut down the tissue from the paper with a surgical knife, make paraffin embedding and section-cutting, then stain and take the microscopic examination.

If the multi-holed cutting fine needle is used, the operation method is as follows:

(a) Select a suitable puncture needle according to the location of the focus
(b) Select the most suitable puncture spot and advancing route, measure the distances from the puncture spot to the anterior surface of the focus as well as to the posterior edge.
(c) Use the surgical knife to pierce the skin or cut a small incision after local anesthesia, if the puncture is percutaneous.
(d) The needle must be pierced vertically into the focus or the tumor.

20.1.7.4. *Clinical Evaluation*

As the fine needle histological examination can obtain a sample of the histological examination, a precise pathological diagnosis can be acquired. It is reported that the accurate diagnostic rate is 88–93%. It has no serious complications. The matters needing attention are the same as those of the aspiration cytological examination.

20.2. THE APPLICATION OF PUNCTURE UNDER THE GUIDANCE OF ULTRASOUND IN CLINICAL TREATMENT

20.2.1. The Application of Percutaneous Trans-Biliary Tract Puncture with Tubal Drainage Under the Guidance of Ultrasound in Acute Diseases of the Biliary Tract

20.2.1.1. *Indications*

Biliary tract obstruction due to causes such as stone, ascaris, tumor or post-operative stenosis of the biliary tract (which will secondarily cause the increase in the biliary pressure), and infection, has proved by ultrasonic imaging that patients with distinct dilatation of the extra-

hepatic or intra-hepatic biliary tract may be treated by this drainage method (US-PTCD). This method cannot be done in patients with serious impairment in the coagulating mechanism and in patients with a bleeding tendency, or poor liver function with large amount of ascites, or with a malignant tumor inside the liver. In the case where there is no marked dilatation of the intra-hepatic or extra-hepatic biliary tract, of which tubal grainage is not easily done, this manipulation is also not suitable.

20.2.1.2. *Preparation of the Apparatus*

Real-time ultrasonic imaging apparatus with the puncture probe is used. A PTC needle is 15–20 cm in length, with outer caliber 0.7 mm and inner caliber 0.5 mm is used. The oblique plane of the needle tip is 45°; the PTCD needle is 12–15 cm in length, with outer caliber 1.4 mm, inner caliber 1.0 mm; the PTCD catheterizing filament is 100 cm or 45 cm in length, the diameter is 0.9–1.0 mm; and the puncture needle with plastic encapsulated cathether produced by Shanghai Syringe Factory is used, its outer caliber is 1.3 mm, inner caliber 0.9 mm, and it is 25–28 cm in length.

20.2.1.3. *Method of Manipulation*

The probe, ultrasonic transmittable coupling agent and puncture needle are all sterilized routinely, and pre-manipulation preparations were made. The patient is usually assumes the supine position. Based on ultrasonic imaging, the point of puncture selected is principally where the biliary tract is markedly dilated, or the dilated biliary tract above the obstruction is selected. The smallest caliber of the tract the author selected is 1 cm. When the puncture has been determined, the skin is sterilized, the towel is spread and local anaesthesia is applied; a small incision is made on the skin, the incision is made as deeply through the whole abdominal wall from the skin as possible. The angle of puncture is determined and the fixation devices well readjusted, then puncture is carried out. When the puncture has reached the abdominal wall, the patient is asked to breathe normally and to hold his breath temporarily. Observe the advancing process of the linear or dot-like echo of the tip of the needle. When the oscilloscreen reveals that the tip of the needle is approaching the anterior wall of the biliary tract the depression of the biliary wall can be seen. Then puncture into the biliary cavity with force. At this point of time, there may be a feeling of falling into emptiness and a strong echo of the needle tip appears inside the biliary tract. The core of the needle is withdrawn. Bile flows out or is aspirated, this means that the puncture has been successful. At this point of time, the catheterizing filament is inserted through the catheter (or needle tract). The catheter is then inserted upward about 4–6 cm to the distal part of the biliary tract along the catheterizing filament, and the drainage tube is fixed.

20.2.1.4. *Clinical Evaluation*

Since US-PTCD is done closely under direct view of the naked eyes, it has greatly overcome the blindness and hazards of puncturing at the bed-side or under the guidance of x-ray in the past. The manipulation of this method is convenient with a high rate of successs. The

Union Hospital, affiliated to Fujian Medical University, has done 22 cases of acute diseases of the biliary tract due to obstruction of the biliary tract using US-PTCD. The results demonstrated the total success of the 22 cases, and the rate of success was 94% for tubal drainage. It took only about 10 minutes to complete the whole manipulation procedure if it was skillfully done. It is an effective measure to directly lower the pressure of the biliary tract system. It has practical values in curing acute diseases of the biliary tract. Particularly to those patients in the late stage of cholangitis or to the senile weak patients with serious liver and multiple visceral damage, using US-PTCD by drainage will decrease the biliary pressure quickly. It has more important clinical values in decreasing the mortality rate and the rate of residual stone after an operation.

20.2.1.5. *Complication and Key Points Regarding the Technique*

Usually, there are no serious complications. Among the author's 22 cases of biliary tract puncture drainage, there were no hemorrhage, biliary fistula, septicemia and pneumothorax occurring during and after the manipulation. Proven by operation, a sinus was formed by the passage of the drainage catheter adherent to the surrounding tissues 3–4 days after US-PTCD manipulation. For the purpose of raising the rate of success in puncture, drainage and the effects of the treatment, the following key points regarding the technique should be noticed:

(a) The puncture target and puncture passage should be selected correctly. The ideal passage the author considers is the 6th–7th intercostal space near the junction of the costocartilage. The point of the puncture here is at the convergence of the right hepatic duct and the common hepatic duct. The advantages of this passage are:
   (i) There are no big blood vessels in this passage, the portal vein is at the dorsal side of the biliary tract;
   (ii) The direction of the trend of the biliary tract here is straight so that it is easily revealed by ultrasonics;
   (iii) The angle of puncture is easily regulated;
   (iv) The biliary tract here is stable, the puncture needle gets into the bile duct easily and the drainage tube is also easily fixed.

(b) The angle for advancing the needle during puncture should be correctly regulated, the proper angle is about 10°. If the angle is too small (as in the case of no marked dilatation), the biliary tract will cause the posterior wall of the biliary tract to be perforated and hence injure the portal vein, also the tube for drainage is not easily applied. Too big an angle will cause the puncture needle to slide easily along the anterior wall of the biliary tract, and it will not easily puncture into the lumen of the bile tract.

(c) In order to quicken the decrease of the pressure inside the biliary tract and to raise the effects of the treatment, when the puncture is successful, the bile inside the dilated bile tract and/or gall bladder should be aspirated as much as possible, then irrigated with antibiotic fluid, finally, retaining the antibiotic inside the ductal cavity.

(d) In the first few days of retaining the drainage tube, frequent irrigation is done. Otherwise, bile clay or inflammatory material will obstruct the drainage tube, causing a failure in drainage.

20.2.2. Treatment of Cystic Diseases by Percutaneous Puncture Under the Guidance of Ultrasound

There are many kinds of commonly seen cystic diseases in the clinic, such as liver or kidney cysts. Small cysts usually have no clinical symptoms, but when the cyst reaches to a certain volume, it will press on the surrounding tissues, inducing distension pains or other clinical symptoms. In the past, surgical incision was usually done, which is certainly not an ideal method. Along with the application of percutaneous puncture under the guidance of ultrasound, quite a lot of units nowadays apply the puncture and sclerosing treatment of liver and kidney cysts under the guidance of ultrasound.

20.2.2.1. *Indication*

Cysts in the liver, kidneys and other parts diagnosed by U-ultrasound, without tendency to bleed, can be treated by the puncture sclerosing treatment.

20.2.2.2. *Preparation of the Apparatus and Medicine*

The real-time imaging apparatus with puncture probe is used. The puncture needle is a percutaneous liver puncture needle, the wider one is no. 18–19, the smaller one is the no. 21–22 needle. The sclerosing agent can be selected according to the case. According to literature reports in China at present, a high concentration (above 95%) of alcohol is used, tetracycline or sodium morrhuate may also be used.

20.2.2.3. *Method of Manipulation*

The patient assumes the supine position (for treatment of cyst of the liver) or prone position (for treatment of cyst of the kidney). When the point of puncture and the route are determined, the skin is sterilized routinely. The towel is spread and the puncture probe that was being sterilized is changed. Again, examine the position of the cyst, determine its distance to the skin and the angle of puncture, the angle of the probe is fixed after local anaesthesia is applied. Supervising the oscilloscreen of the B-ultrasound, the puncture needle is punctured into the cyst above 1/3 of the central line of the cyst. After as much of the cystic fluid as possible has been aspirated, use a different group of medicine to irrigate the cystic cavity, the sclerosing drug is injected and retained with an amount equivalent to 1/4 to 1/6 of the cystic fluid aspirated. But the maximum volume should not exceed 15 to 20 cc on any one occasion. After manipulation, the patient may properly move his position and has to be kept for observation for 12 to 24 hours. With big cysts, the puncture with sclerosing treatment may be done several times and has to be followed up with the B-ultrasound for 3 to 6 months.

20.2.2.4. *Clinical Evaluation*

One important feature of using the sclerosing treatment for the cyst of the liver, kidneys and other parts by means of percutaneous puncture under the guidance of B-ultrasound is to

avoid the sufferings caused by an operation. It is easy to manipulate, safe and effective and can be done many times. Its total rate of effectiveness is above 90%, among these the healing rate may reach 70–80%. The Union Hospital, affiliated to the Fujian Medical University, used a high concentration of alcohol and tetracycline fluid as the sclerosing agents to treat the respective cysts. The results showed that alcohol treatment was somehow better than tetracycline fluid. There are reports in China stating that using soldium morrhuate as the sclerosing agent lead to even better results.

20.2.2.5. *Complications and Precautions*

Usually there are no serious complications and only some of the patients have the feeling of distension pain at the liver or kidney area or discomfort at the side. Some of the patients may have transitory hematuria under the microscope. There is no need for special treatment. Points to be noted:

(a) Contraindiction should be strictly controlled, such as serious incomplete functioning of the liver or kidney, poor bleeding mechanism and coagulation of blood, or a weak general condition such that the patient cannot bear the puncture;
(b) The passage of the puncture must be free of the big blood vessels;
(c) For big cysts with thick walls multiple and repeat treatments are adopted. Good results may be obtained by the local or general use of antibiotics;
(d) Using alchohol as the sclerosing agent for poor liver functioning should be done with great care.

20.2.3. Puncture Drainage of An Abdominal Abscess Under the Guidance of Ultrasound

An abdominal abscess is a serious disease and it is also a serious complication in operations. A lingering high fever brings great suffering to the patient. Even when a large amount of antibiotics is used for treatement, the effect is still very poor. If the correct diagnosis and drainage are not done on time, the mortality rate may reach to around 70%. The methods of incision and drainage used in the past brought quite a lot of difficulties and increased the suffering of the patient due to blindness in the diagnosis before operation and the lack of sufficient understanding of the position and range of the abscess. On the other hand, percutaneous puncture drainage under the guidance of ultrasoundic imaging has proved a convenient, safe and very effective method for correct diagnosis and for the treatment of abdominal abscesses, thus gaining a breakthrough in the progress.

20.2.3.1. *Indication*

Ultrasonic imaging can show the position, image and the relationship of the abscess of the abdomen, including the abscess of the abdominal wall, subdiaphragmatic abscess, pelvic abscess, abscess of retroperitoneal space, abscess between intestinal loops, and abscess inside the abdominal viscera. For the viscera, except the abscess between the intestinal loops which

is not easily revealed, particularly for the deep abscess of the abdomen such as the subdiaphragmatic and liver abscesses, renal and perirenal abscess, and the abscess around the pancreas, remarkable results can be obtained by percutaneous puncture and aspiration of abscess or tubal drainage under the guidance of ultrasound.

20.2.3.2. *Preparation of the Apparatus*

The real-time imaging apparatus with the puncture probe is used. If the puncture is done by indirect guide and with localization of the intersection, the general real-time imaging apparatus is used. If the puncture needle is used only for aspiration of pus and instilling the medicine, a small needle 15–20 cm in length, with an outer caliber of 0.7 mm is used. If the pus is sticky or during tubal drainage the no. 12–14 big needle, which is 15–20 cm in length is used. A catheterizing filament, i.e the catheterizing filament used for blood vessel catheterization, is 45–80 cm in length, 0.9 cm in width and soft at the tip. The drainage tube, 8F blood vessel catheter, or pig tail catheter 20 cm in length with a hole at the side, can be sheathed on a wide needle for puncturing.

20.2.3.3. *Method of Manipulation*

For the puncturing and aspiration of pus and drainage of the abdominal abscess, a special puncture probe for puncture under direct guidance may be used. In case the abscess is shallow and the area is rather big, bodily surface localization with ultrasound may be used too (method of + figure intersection) to ascertain the point at which the needle is advancing and the depth of the puncture. While puncturing, the ultrasonic probe may undergo monitoring observation at the side of the point of puncture. According to the author's understanding, the rate of success is also high. Puncture under direct guidance is used only when the abscess is deep and the volume is rather small. Before puncturing, the viscosity of the pus should be determined and the size of the needle selected. After the pus is aspirated by the puncture, bacteria culture and a test for sensitivity to the drug should be done. When the puncture is successful, try to aspirate as much pus as possible and instill the sterilized, normal saline for irrigation and withdrawal. Alternatively, an antibiotic fluid may be used for irrigation and an antibiotic drug is then instilled for better results. Big abscesses or multiple abscesses may undergo multiple punctures or multiple-point puncture. The drainage tube may also be inserted for continuous drainage.

20.2.3.4. *Clinical Evaluation*

Abdominal abscesses is a common disease found clinically. Ultrasonic imaging has a unique value in discovering abdominal abscesses. The rate of success of puncture to aspirate pus under the guidance of ultrasound is very high, it is almost 100% successful. It will also make correct diagnosis and is effective in the treatment of pus evacuation, greatly decreasing the suffering on the part of the patient brought about by operations. Therefore, puncture under the guidance of ultrasound has an important significance both in the diagnosis and treatment of abdominal abscesses.

20.2.3.5. *Complications and Precautions*

Usually, there are no serious complications, but if the technique is not skillfully mastered, it will induce failure in the puncture or aspiration of pus or failure in tubal drainage, the spleen or lung may be injured during the puncture of the subdiaphragmatic abscess, resulting in hemorrage or pneumothorax complications. In order to raise the rate of success of puncture and to prevent the occurence of complications, the following points should be noted:

(a) The manipulation process should be carried out strictly under the guidance of ultrasound;
(b) According to the nature of the abscess, try to use small needles for puncturing as much as possible. If the pus is sticky, a bigger needle is chosen for the puncture and aspiration of pus;
(c) The position of the tip of the needle should be noted. Avoid too-deep punctures in order to prevent the blocking of the needle hole by the precipitate of the deep layer of the abscess cavity. Also, avoid close contact to the lateral wall of the abscess cavity in order to prevent blockage of the needle hole by the tissue fragments;
(d) Avoid using too much force while aspirating the pus, to prevent the aspiration of the surrounding tissues, hence blocking the tract of the needle. While aspirating sticky pus, irrigate with normal saline simultaneously to dilute the pus to facilitate drainage;
(e) When puncturing the subdiaphragmatic abscess, avoid injuring the spleen, diaphragm and lung tissues.
(f) For puncturing drainage of the retroperitoneal abscess, the needle should be inserted through the side or back in order to prevent contamination of the abdominal cavity;
(g) The puncture manipulation time should not be too long each time, particularly for senile and very weak patients. If the drainage tube is retained, it should be irrigated with normal saline to keep the drainage tube patent.

20.2.4. Application in Other Aspects

Interventional ultrasound has been extensively applied in clinical diagnosis and treatments. Besides the above-mentioned drainage of the biliary tract, sclerosing treatment of cysts, puncturing for aspiration and drainage are commonly used. Nowadays, it is also gradually applied in many fields, as discussed below.

20.2.4.1. *Treatment of Ascaris in the Biliary Tract with Endoscope Under the Guidance of Ultrasound*

According to reports in China, under the supervision of real-time imaging, the endoscope using snare passing into the biliary tract to encapsulate ascaris has a rate of success reaching 77% (27/36), which is higher than that of the control group catching ascaris under x-ray television (60%). It has the advantages of being non-traumatic and non radioactive. It can be used repeatedly.

20.2.4.2. *Percutaneous Transport Vein Suppository Therapy Under the Guidance of Ultrasound (PTPVO)*

Traditional portography is usually done by percutaneous puncturing of the spleen, which is hazardous. Its rate of success is about 60%. Percutaneous transhepatic portography under the guidance of ultrasound (BU-PTP) may correctly control the direction in which the needle advances and the depth. 86 cases in the Chiba University in Japan have done the BU-PTP 96 times with complete success without any serious complications. Having been proven by BU-PTP that a patient with esophageal varcosis may use the catheterizing filament to replace the catheter, the bleed point may be approached as closely as possible, then the suppository (such as coagulase gelatin sponge) or fine steel ring is injected. Chiba University in Japan reported that among the 60 cases with complete success in 79 times of suppository treatment, 40 cases underwent gastric lavage among suppository treatment with 39 cases getting a complete stop to bleeding.

20.2.4.3. *Diagnosis and Treatment of Diseases of the Urological System*

Besides being able to puncture the renal abscess and perirenal abscess for aspiration or tubal drainage, ureterostomy can also be done in acute urinary tract obstruction under the monitoring of the sonogram. These are simple and effective measures for emergencies. To eliminate ureteral stones, the intraureteral stent can be used with the supplement of an x-ray television. A small stone may be pushed into the bladder, if the stone does not pass smoothly through the orifice of the bladder, the stone may be removed by cystoscope. For a big stone, stone dissolving therapy can be done according to the nature of the stone. The corresponding acidic or alkaline stone-dissolving fluid can be used to dissolve the stone. The stone may also be removed by pelvoscopy or by using a capped basket through the ostomy. In addition, puncturing the bladder under the guidance of real-time imaging, inserting the tube or cyctostomy are all safe and reliable methods, with high rates of success.

20.2.4.4. *Treatment of Diseases of the Heart and Chest*

Pericardial puncture under the guidance of real-time ultrasound provides a direct view which may avoid damaging the heart. It is both a safe and ideal method of diagnosis and treatment, and it may also accurately select the position for myocardial biopsy. For encapsulated effusion of the thorax or pyothorax, the puncturing aspiration treatment under the guidance of ultrasound is far more convenient and effective. For obstinate tuberculous cavity, lung abscess and bronco-dilatation, one may apply direct puncture aspiration, contract graphy, local medication, or insert the catheter to create a favorable condition for radical treatment. Pericardial and thoracic puncture will more effectively avoid injuring the lung tissues containing gas and lessen the occurrence of pneumothorax or haemothorax complications.

20.2.4.5. *Application for the Treatment of Tumor*

Locally and abroad, there are quite a lot of reports about puncture under the guidance of ultrasound using the injection of high concentration alcohol or other drugs into the tumor

to control the development of the tumor. Haraela reported in 1984 that undergoing selective biopsy for the small focus of the prostatic gland is safe and accurate. In a frozen section of the prostatic gland, by ultrasound monitoring, ice ball formation can be mastered and also the implantation of the radiative nucleoli can be monitored to treat carcinoma of the prostatic gland through the abdomen.

20.2.4.6. *Application in Surgical Operations*

In recent years, interventional ultrasound has been widely used during surgical operations. Small foci in many viscera or deep parts of the tissues such as the small focus seated deeply in the cerebral parenchyma and inside the liver and kidney (such as stone, small tumor), and even the big stones in the renal pyramid or renal calix, usually cannot be detected easily during the operation or cannot be ascertained by palpation. In the past, the help of a probe or puncture was needed for understanding, but sometimes it would not be effective. Therefore, a special probe is used to carry out direct examination of the viscera or tissues being operated on. It has the advantages of having a very high rate of resolution, less overlapping of tissues and less interference. The sonogram is especially clear, the minute focus may be explored during the operation and it has a special value in understanding its position and relationship with the surrounding blood vessel tissues. The stone in the biliary tract, inside the liver, or in the urinary tract can be explored by ultrasound during the operation and accurately dealt with one by one. Small tumors of the adrenal gland or pancreas, such as phenochromocytoma and islet cell adeno carcinoma, cannot be ascertained by routine bodily surface examination, but they will have their positions ascertained during the operation, hence remarkably raising the rate of surgical excision, increasing the rate of radical treatment of the focus or tumor. Hence it has important practical clinical values.

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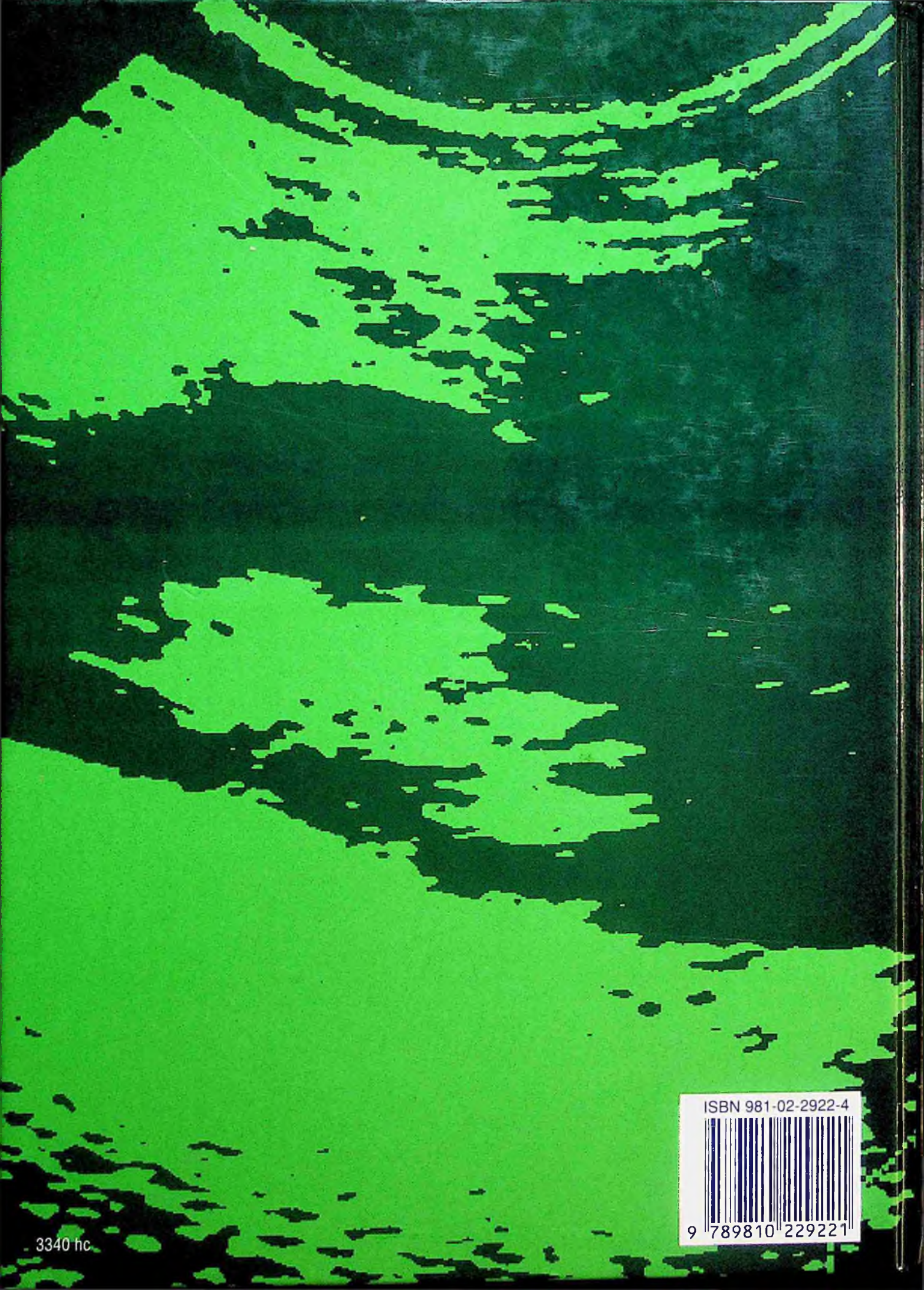

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