Chapter 1: Ultrasound Nomenclature, Image Orientation, and Basic Instrumentation

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Ultrasound waves are sound waves that have a frequency exceeding 20,000 Hz. When sound waves are transmitted into the body, they interact with tissues and become attenuated (reduction of signal strength) by absorption, scattering, and beam divergence. Reflected sound waves (echoes) are displayed on an image as varying shades of gray (gray scale) relative to their intensity and are dependent on the number of binary digits that can be stored in the digital memory of the equipment.

Echoes are created when emitted sound waves encounter tissues with an acoustic mismatch. This causes some sound waves to continue traveling and others to be reflected back to the transducer. These reflected echoes are then converted into an image that is displayed on a monitor.

Ultrasound Nomenclature

See Exhibit 1.1

- Echogenic: the ability of a structure to produce echoes
- Anechoic: no echoes and sonolucent—appears black on ultrasound (Figure 1-1)
- Hypoechoic: less reflective and low amount of echoes when compared with neighboring structures, appears as varying shades of darker gray (Figure 1-2)
- Hyperechoic: highly reflective and echo rich when compared with neighboring structures, appears as varying shades of lighter gray; the term echogenic is often used interchangeably (Figure 1-3)
- Isoechoic: having similar echogenicity to a neighboring structure (Figure 1-3)

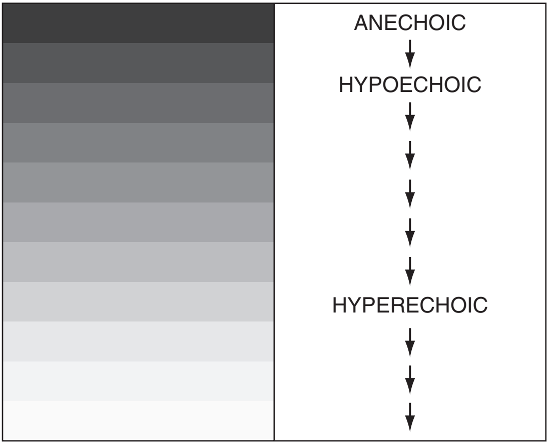

Exhibit 1-1 Ultrasound nomenclature.

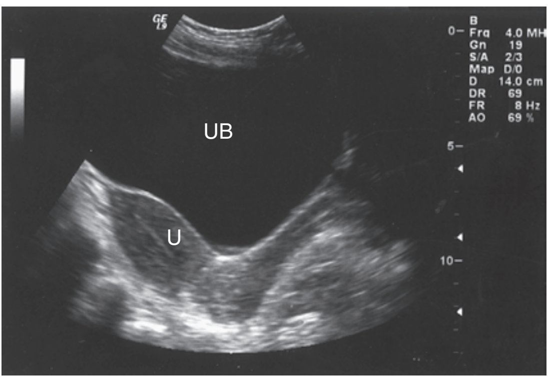

Figure 1-1 Anechoic. A transabdominal sagittal image of the female pelvis demonstrating the anechoic distended urinary bladder (UB) anterior to the uterus (U). Note the lack of echoes within the urinary bladder since it is filled with urine.

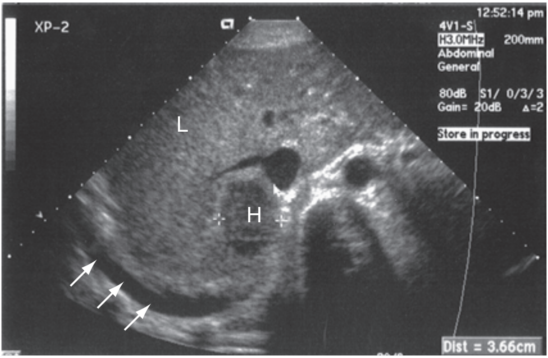

Figure 1-2 Hypoechoic. A transabdominal transverse image of the liver (L) demonstrating a hypoechoic (H) mass within the right lobe of the liver. Also, note the anechoic fluid (arrows) representing a right-sided pleural effusion.

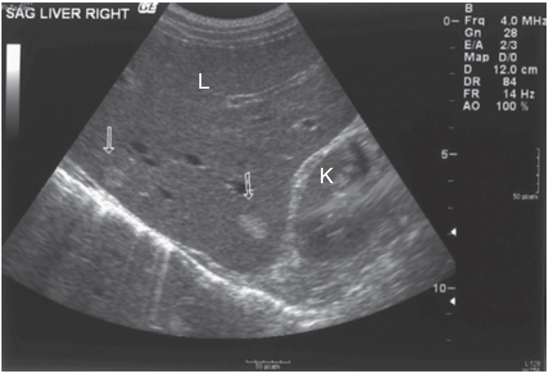

Figure 1-3 Hyperechoic and isoechoic. A transabdominal sagittal image of the right upper quadrant. The liver (L) contains two areas (arrows) that are hyperechoic when compared with the rest of the moderate echogenicity of the liver parenchyma. The kidney (K) is isoechoic to the liver.

Ultrasound Texture

- Homogeneous: organ parenchyma is uniform in echogenicity (Figure 1-4).
- Inhomogeneous or heterogeneous: organ parenchyma is not uniform in echogenicity (Figure 1-5).

Ultrasound Artifacts

Artifacts may be caused by the following:

- Ultrasound waves interacting with tissue
- Machine malfunction
- Improper operation of machine (such as control settings)
- Motion of the patient (such as breathing)

Common Ultrasound Artifacts

- Reverberation (ring down): This occurs when sound travels with minimal to no attenuation

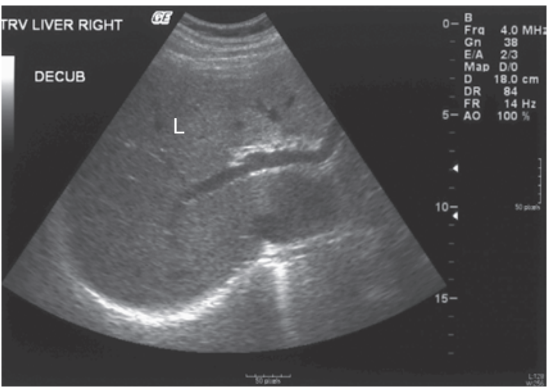

Figure 1-4 Homogeneous. A transabdominal transverse image of the liver (L) demonstrating the normal uniform texture of the liver. Anechoic structures within the liver represent vessels and ducts.

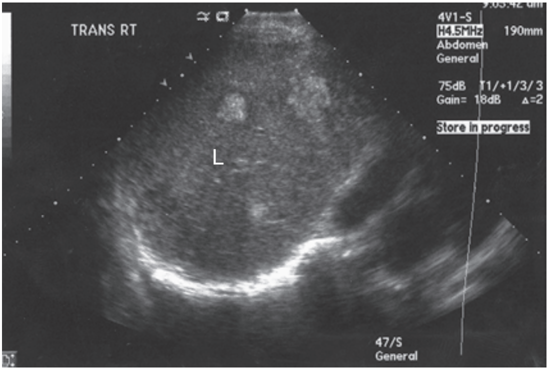

Figure 1-5 Inhomogeneous. A transabdominal transverse image of the right lobe of the liver (L). Note the nonuniformed appearance of the liver parenchyma representing metastatic liver disease.

through a fluid-filled structure. It is displayed as multiple parallel echogenic lines equidistant from each other. They become fainter as sound travels deeper into the structure (such as the anterior region of a filled urinary bladder or large cystic mass). Reverberation can mimic solid elements in an otherwise cystic organ or a mass (Figure 1-6). Changing the scanning angle of approach may resolve this artifact.

- Comet tail: This is a type of reverberation artifact. It appears as a dense, tapering trail of echoes distal to a strongly reflecting structure. Metallic objects (such as surgical clips and bullet fragments) and adenomyomatosis of the gallbladder may produce comet-tail artifacts (Figure 1-7).
- Acoustic enhancement (posterior enhancement, good through transmission): This is seen as a hyperechoic pattern posterior to a poorly or nonattenuating structure or mass (e.g., a cyst).

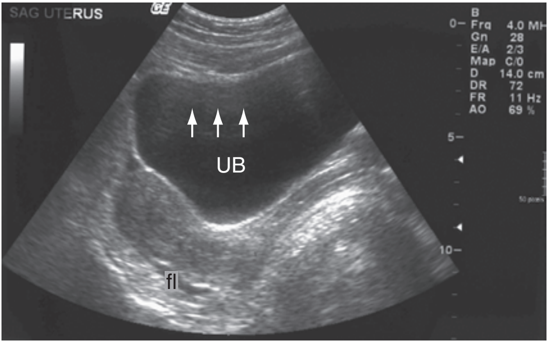

Figure 1-6 Reverberation artifact. A transabdominal sagittal image of the female pelvis demonstrating an anechoic distended urinary bladder (UB) with anterior reverberation (arrows) artifacts. Note the minimal amount of fluid (fl) in the posterior cul-de-sac posterior to the uterus (U).

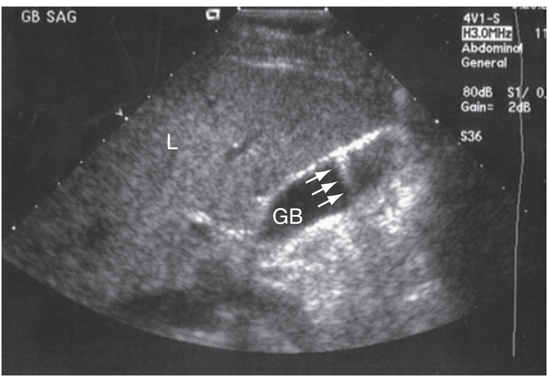

Figure 1-7 Comet-tail. Transabdominal sagittal image of the gallbladder (GB) with a dense tapering trail of echoes posterior to a strongly reflecting structure (arrows). Liver (L).

Echoes posterior to a cyst look “brighter” than adjacent echoes (Figure 1-8).

- Attenuation: This is the lack of sound transmission through a mass. It generally indicates a solid internal consistency (Figure 1-9).
- Shadowing: This appears as a hypoechoic pattern posterior to highly attenuating structures (e.g., calcifications such as gallstones or plaque, bone, and air). Echoes posterior to these structures look “darker” (a reduction in the amplitude of the echoes) than adjacent echoes (Figure 1-10). Shadowing is described as “clean” or “dirty.” “Clean” shadows present posterior to calcifications, bone, plaque, and dense structures such as intrauterine contraceptive devices. Shadows from these structures are sharply demarcated. Shadows posterior to air or bowel are referred to as “dirty” shadows, and they lack the clean, sharp side edges.

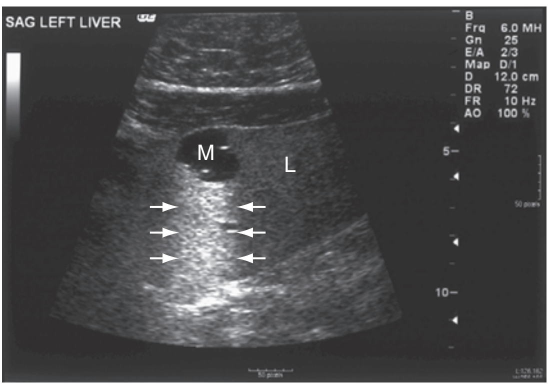

Figure 1-8 Enhancement artifact. A transabdominal sagittal image of the left lobe of the liver (L) demonstrating a cystic mass (M). The liver parenchyma posterior to the cyst is enhanced (arrows) because of the lack of sound attenuation.

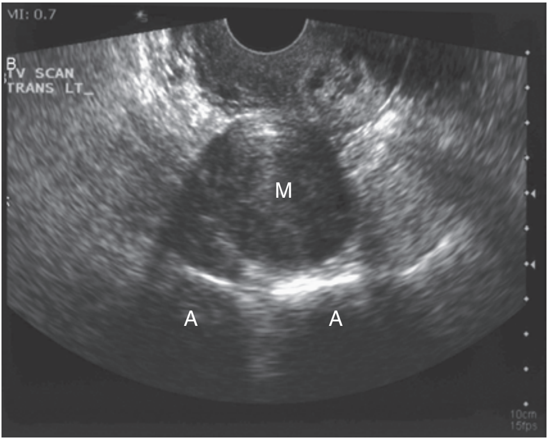

Figure 1-9 Attenuation artifact. A transvaginal coronal image demonstrating a hypoechoic solid mass (M). Note the absence of sound transmission posterior to the mass caused by attenuation (A) of sound waves.

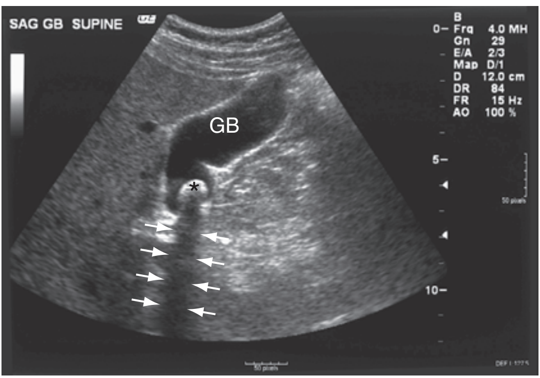

Figure 1-10 Shadowing artifact. Transabdominal sagittal image demonstrating the gallbladder (GB) with an echogenic focal area (*) representing a gallstone casting a posterior acoustic shadowing (arrows).

Air-filled bowel loops near the gallbladder can mimic gallstones (see Chapter 3).

- Slice thickness artifact: This occurs when a fluid structure lies adjacent to a soft-tissue structure. The ultrasound beam strikes both simultaneously, producing low-level echoes in the fluid structure. These low-level echoes can be mistaken for pathology. Changing the scanning angle of approach can resolve this problem.

Ultrasound Description of Masses

Simple Cyst

- Completely anechoic, smooth walled, with posterior enhancement
- Reverberation may be seen on the anterior wall of the cyst (Figure 1-11).

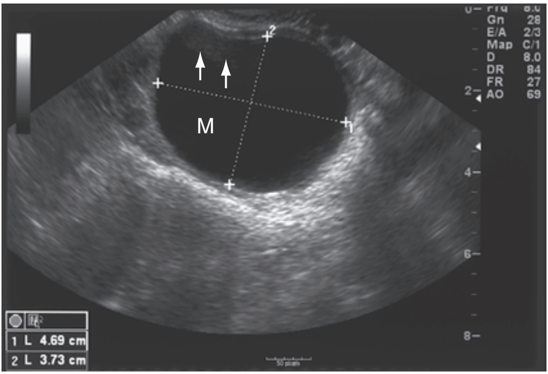

Figure 1-11 Simple cyst. A transabdominal sagittal image of a female pelvis. A unilocular, anechoic, smooth-walled mass (M) with posterior enhancement is demonstrated that meets the criteria for a simple cyst. Note the minimal amount of reverberation artifact (arrows) on the anterior aspect of the cyst similar to what is visualized in a distended urinary bladder.

Complex Cyst

- Anechoic, smooth walled, with posterior enhancement
- Septations that appear as echogenic hair-like strands within mass (Figure 1-12)
- Multilocular compartments (cluster of cysts) (Figure 1-13)
- Internal low-level echoes that may indicate hemorrhage or infection (Figure 1-14)
- Fluid-fluid layers that may represent blood, fluid, or fat layers
- Calcification that appears as highly reflective echoes (hyperechoic) with posterior shadowing

Solid Mass

- Homogeneous or inhomogeneous
- Hypoechoic to hyperechoic (Figure 1-15)
- May attenuate sound partially or completely

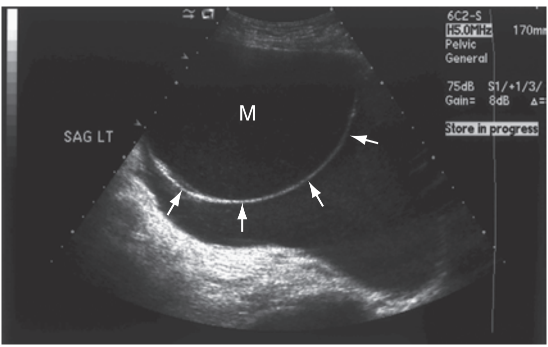

Figure 1-12 Complex Cyst. A transabdominal sagittal image of the left adnexa of a female demonstrating a large cystic mass (M) containing a thin, echogenic, hair-like structure (arrows). This is consistent with a septation in a benign complex cyst.

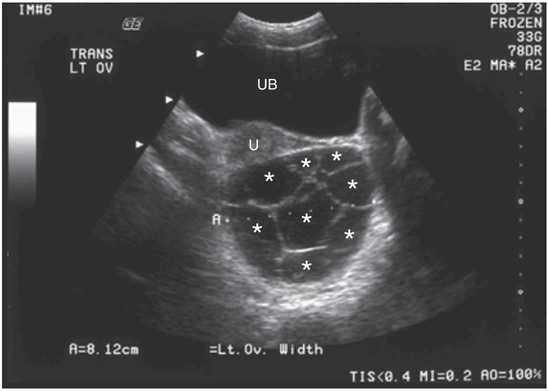

Figure 1-13 Complex Cyst. A transabdominal transverse image of the left ovary demonstrates a large cystic mass with multiple loculations/compartments (*). Note the appearance, which looks like a cluster of cysts. This is characteristic of a multilocular cyst due to the absence of solid components and absence of irregularities. Urinary bladder (UB), uterus (U).

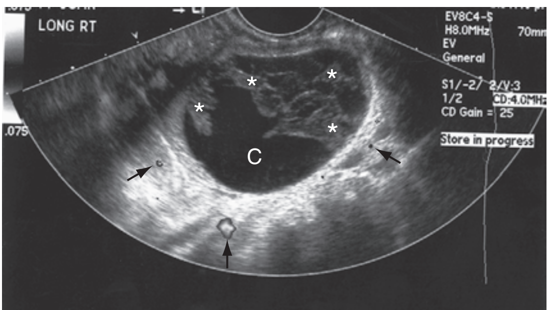

Figure 1-14 Complex cyst. A transvaginal sagittal image of the right adnexa in a female patient demonstrating a cyst (C) containing internal solid echogenic components representing hemorrhage (*). Echogenic hemorrhage within a cystic mass may mimic a malignant tumor. Doppler may be able to detect internal vascularity, which is frequently seen in malignant tumors. Note the presence of Doppler signals outside the cyst (arrows).

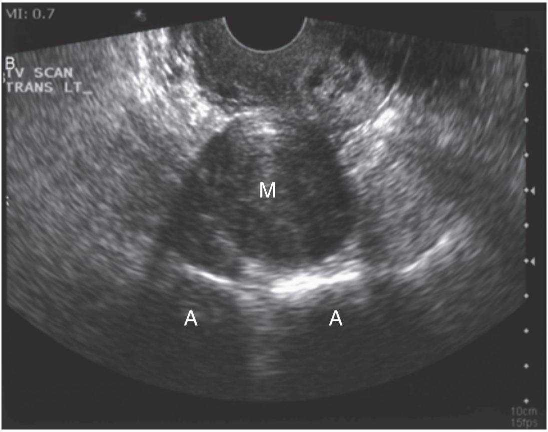

Figure 1-15 Solid mass. A transvaginal coronal image demonstrating a hypoechoic solid mass (M), which is inhomogeneous and has partial sound attenuation (A).

- May contain anechoic or hypoechoic areas within the solid mass representing necrotic changes
- Posterior enhancement that may be seen when necrotic changes occur

Ultrasound Sectional Views

- Sagittal plane (longitudinal)—obtained using either an anterior or posterior approach
- Transverse plane (axial)—obtained using an anterior, posterior, or lateral approach
- Coronal plane (sagittal or transverse)—obtained using a lateral approach

Sectional Views and Image Orientation

See Exhibit 1.2

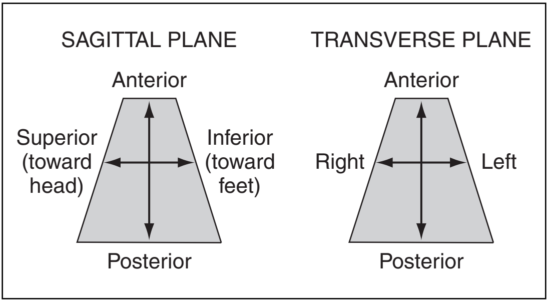

Exhibit 1-2 Sagittal plane and transverse plane.

Instrumentation

It is beyond the scope of this book to discuss the technical aspects of scanning in detail; however, this section briefly discusses some of the most frequently used functions of the ultrasound machine. It is recommended that practitioners learn the different capabilities of their own equipment to optimize image quality and diagnosis.

- Keyboard: various capabilities as provided by manufacturer
- Overall gain control: used to amplify all received signals equally (Figure 1-16A–C)
- Time gain compensation: used to "fine tune" attenuated signals
    - Near and far gains: These controls are used to equalize the differences in echoes received from various depths as they are displayed on the screen (Figure 1-16D–E). When compensating for sound attenuation, the near to far gain controls (usually slide pods) should be gradually increased.

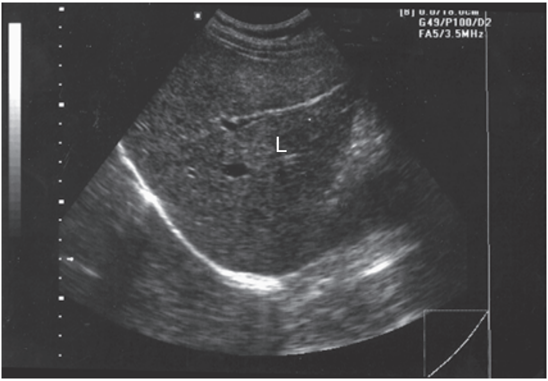

Figure 1-16A Time gain compensation (TGC) and overall gain settings affecting the image quality of the liver (L). Transabdominal sagittal images of the liver. (A) TGC with proper gain settings. The homogeneous liver with midlevel echoes is demonstrated. Note the intensity of the echoes is the same in the anterior, mid, and posterior regions of the liver.

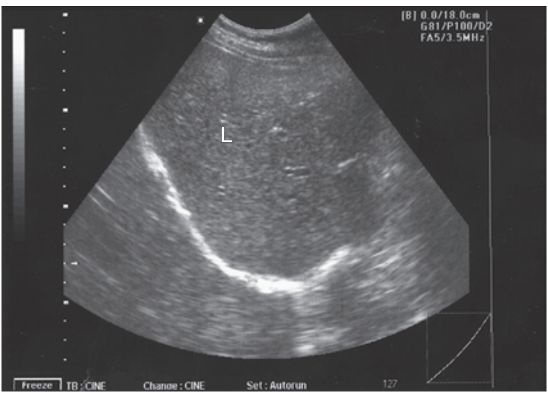

Figure 1-16B (B) TGC with overall gain greatly increased. Note the echogenicity of the liver parenchyma, which is hyperechoic and can mimic liver pathology such as fatty liver disease.

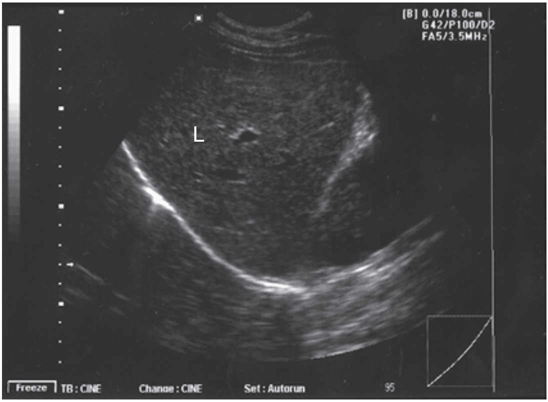

Figure 1-16C (C) TGC with overall gain greatly decreased. The liver appears to be hypoechoic compared with its normal echogenicity as a result of decreasing the overall gain setting too much. This may cause poor visualization of liver parenchyma, which could result in a missed diagnosis.

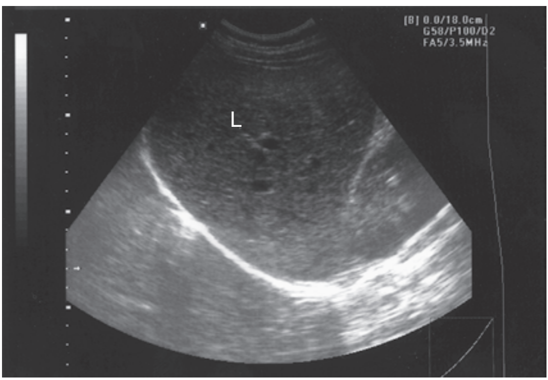

Figure 1-16D (D) TGC with far gain greatly increased. There is increased echogenicity in the posterior aspect of the liver, resulting from improper far gain settings. Small echogenic masses may be missed in this area.

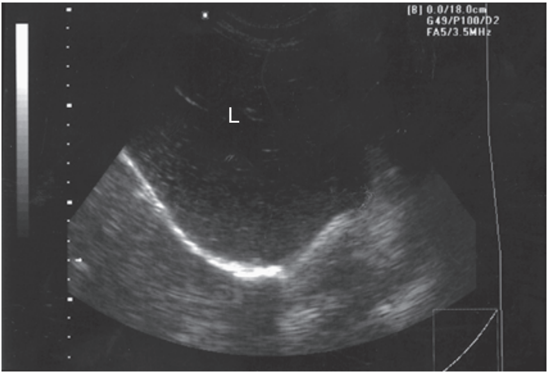

Figure 1-16E (E) TGC with near gain greatly decreased. The anterior aspect of the liver is poorly visualized because of the loss of echoes in the near field. Decreasing the near gain can result in missed pathology.

- Depth: This control is used to adjust the size of the image so that organs and adjacent structures or regions of interest are equally well visualized (Figure 1-17A–C).
- Focal point(s): A control that has one or more toggle buttons. This allows the operator to choose the level at which the ultrasound beam is focused to increase the resolution at a specific point or points. This control should be set at the most posterior aspect of the organ or structure being imaged (Figure 1-18A–C).
- Failure to properly adjust the gain control and/or poor placement of focal point during scanning may result in suboptimal image quality and misdiagnosis.

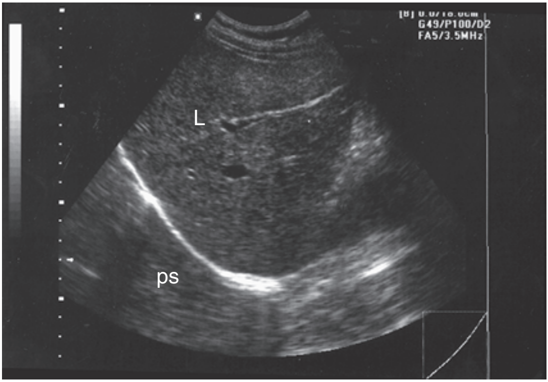

Figure 1-17A Depth adjustments affecting image size. Transabdominal sagittal images of the liver (L). (A) The correct depth control for this patient was at 18 cm. This allows the posterior aspect of the liver and the pleural space (ps) to be evaluated.

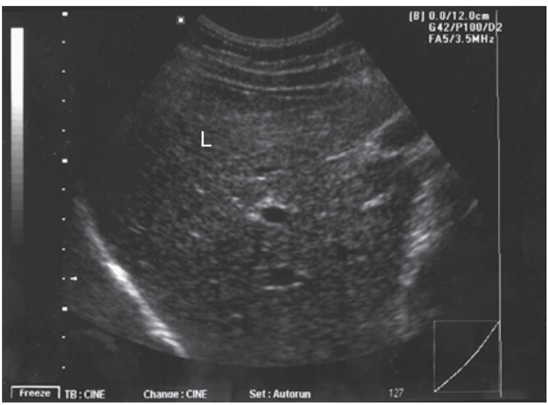

Figure 1-17B (B) The 12-cm depth is too shallow. The posterior aspect of the liver and pleural space was not demonstrated and therefore cannot be evaluated.

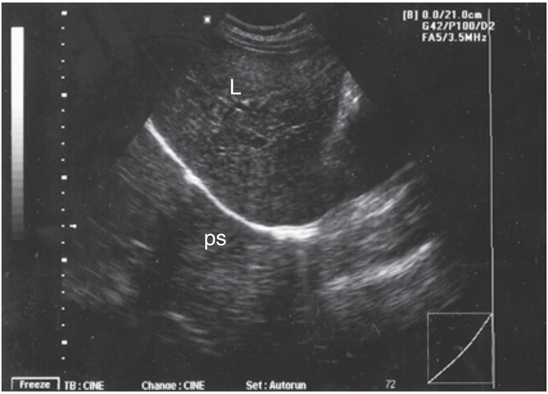

Figure 1-17C (C) The depth was set at 21 cm, which allowed for complete visualization of the posterior aspect of the liver and the pleural space (ps). However, the small size of the image makes it difficult to evaluate the liver parenchyma thoroughly.

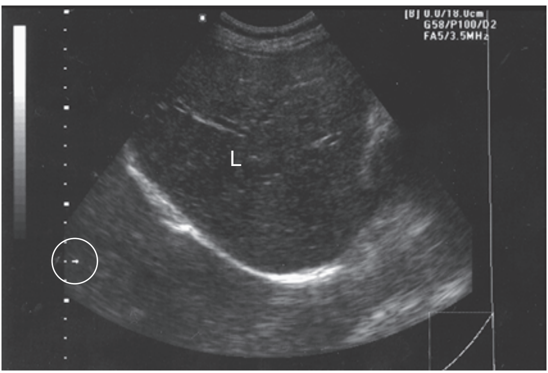

Figure 1-18A Placement of focal point settings (circled) affecting resolution. Transabdominal sagittal images of the liver (L). (A) Demonstrates the focal setting correctly placed just beyond the area being investigated. Note the normal homogeneity of the liver. The anterior, mid, and posterior aspects of the liver are visualized well.

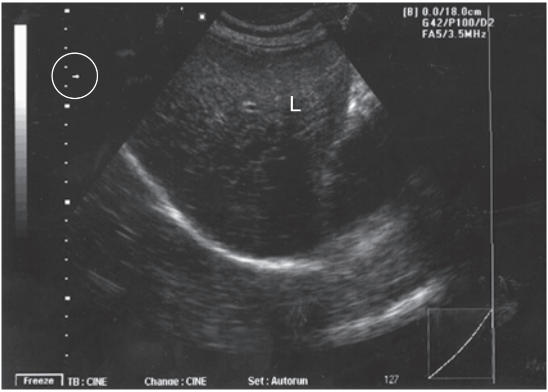

Figure 1-18B (B) The focal setting is placed in the anterior aspect of the liver. There is better resolution in the anterior aspect of the liver; however, the posterior aspect, in the far field, is poorly visualized.

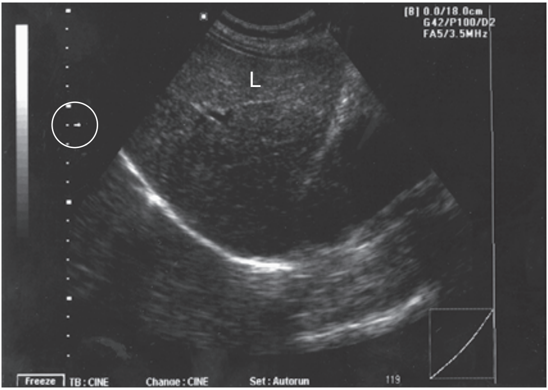

Figure 1-18C (C) Placement of the focal setting around mid depth of the liver demonstrates increased resolution in the near and midfield, but there is a loss of resolution in the posterior aspect of the liver. The decreased echogenicity makes the liver appear such that sound is being attenuated, and this may mimic liver pathology such as fatty liver disease.

Doppler

Doppler systems are used to evaluate blood flow in both large vessels (such as the aorta) and small vessels in structures and organs (such as the testicular artery). Frequently used systems include color, spectral, power, and audible Doppler.

The following are some examples of how Doppler can help in the diagnosis of pathologies:

- Detect presence of flow (such as ruling out ovarian or testicular torsion)
- Distinguish type of flow (arterial, venous, or mixed)
- Evaluate intensity of flow (such as demonstrating increased vascularity in some inflammatory conditions or malignant tumors)
- Establish direction of flow (to determine whether there is reversal of flow such as in portal hypertension)
- Calculate velocity of flow (such as evaluating for renal artery stenosis)
- Identify areas of stenosis or occlusion
- Evaluate integrity of vessels in trauma setting

The examiner must carefully adjust the Doppler flow parameters in order to obtain accurate information. Factors such as motion of the patient, obesity, and slow flow within vessels increase the difficulty in performing Doppler exams.

Ultrasound Transducers

Ultrasound transducers (Figure 1-19) convert mechanical energy to electrical energy and produce images that are displayed in a variety of formats. The most commonly used formats include sector and linear.

Image Formats

<u>Linear Transducers</u>

- The image is displayed as a rectangle or parallelogram (Figure 1-20).

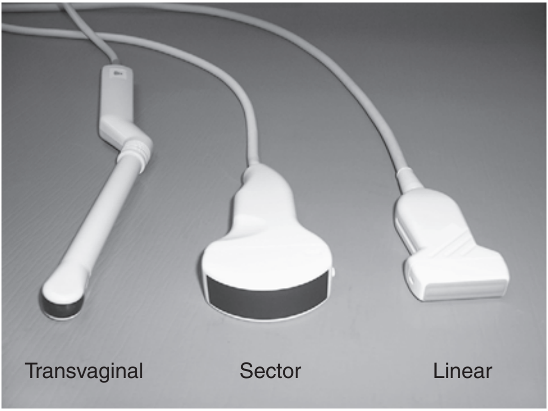

Figure 1-19 Ultrasound transducers. Samples of transvaginal, sector, and linear probes as labeled.

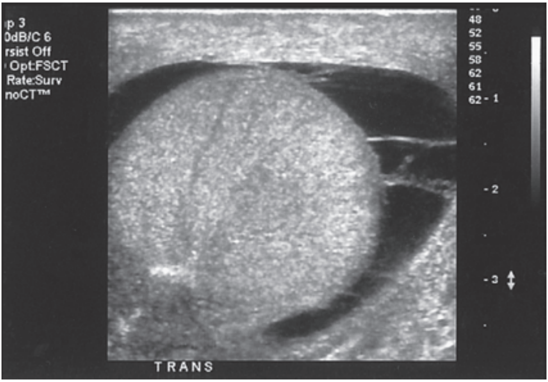

Figure 1-20 Linear transducer display. Sample of an image displayed in a rectangle format.

- The size of the field of view is equal in both the near field (area of sound penetration closest to transducer) and far field (area of sound penetration farthest from transducer).
- Linear transducers are optimal for superficial structures, such as testes.

Sector Transducers

- The image is displayed as a wedge or pie-shaped section (Figure 1-21).
- The field of view is wider in the far field than in near field.
- They are commonly used for routine abdominal and pelvic imaging.

Transducer Frequency

Linear and sector transducers have a range of frequencies generally varying from 2.0 to 12.0 MHz. Transducer selection is based on the type of exam and the patient's body habitus.

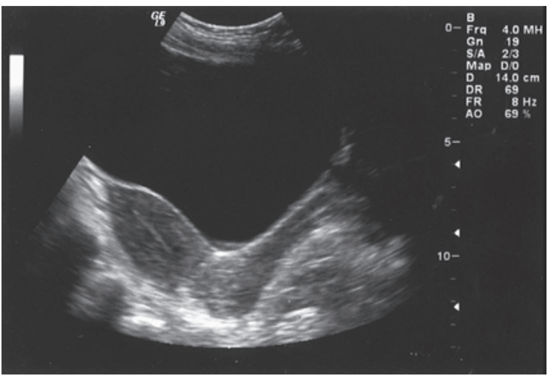

Figure 1-21 Sector transducer display. Sample of an image displayed in a wedge or pie-shaped format.

Low-Frequency Transducer

- Frequency of 2.0 MHz
- Sector format
- Results in increased sound penetration but with loss of resolution
- Suitable for abdominal and pelvic exams in obese patients

Medium-Frequency Transducer

- Frequency range 3.0 to 5.0 MHz
- Generally sector format
- Some 5.0 MHz transducers are in both linear and sector formats
- Sector suitable for imaging most adults

High-Frequency Transducer

- Frequency range of 7.0 to 14.0 MHz
- Linear or sector format
- Results in increased resolution but with reduced penetration
- Sector probes suitable for pediatric patients
- Linear probes best suited for imaging superficial structures

Image Recording

All examinations should be recorded. There are various methods of recording images, including hard-copy prints and DVD and digitally stored images on PACS (Picture Archiving and Communication System). It is very important that the patient's name, identification number, and date of the examination be included on all images.

Technical Points

Errors during scanning are commonly due to the following:

- Technical proficiency of the examiner
- Patient positioning
- Transducer selection

- Adjustment of controls (such as gain setting)
- Improper use of Doppler
- Failure to recognize artifacts and bowel loops that may mimic pathology
- Incorrect measurement of structures and organs

Summary

- Organs and structures are characterized based on the amount of echoes they generate (echogenicity) and how equally distributed these echoes are in soft tissue (homogeneity).
- Solid organs, such as the liver, are moderately echogenic and homogeneous.
- Fluid-filled organs such as the gallbladder are normally anechoic.
- Pathology is often indicated when there is a change in an organ's echogenicity or homogeneity.
- Masses are classified as anechoic, hyperechoic (echogenic), hypoechoic, or mixed in echogenicity.
- The presence of enhancement (sound transmission) is also evaluated to determine tissue characteristics (such as cystic, solid, or complex).
- Technical factors during scanning are critical to the quality of the exam and the accuracy of the diagnosis.