4 Probe Selection, Machine Controls, and Equipment

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INTRODUCTION

A basic understanding of physics and orientation is essential for understanding ultrasound. However, when standing in front of the ultrasound machine, you need to make some concrete decisions about what probe to use, and what buttons to press, in order to obtain a good image—sometimes known as *knobology*.

This chapter covers the basics of probes and probe selection as well as the buttons found on typical ultrasound machines. While these controls are fairly standard, there are variations from machine to machine and the users will need to spend some time familiarizing themselves with the actual equipment they have—preferably before entering the patient's room. Some additional equipment and logistical concerns have also been discussed.

PROBE SELECTION

Probes are generally described by the size and shape of their face ("footprint"). Selecting the right probe for the situation is essential to get good images, although there may be times where more than one probe may be appropriate for a given exam. There are three basic types of probe used in emergency and critical care point-of-care ultrasound: linear, curvilinear, and phased array. Linear (also sometimes called vascular) probes are generally high frequency, better for imaging superficial structures and vessels, and are also often called a vascular probe. Curvilinear probes may have a wider footprint and lower frequency for transabdominal imaging, or in a tighter array (wider field of view) and higher frequency for endocavitary imaging. A phased array probe generates an image from an electronically steered beam in a close array, generating an image that comes from a point and is good for getting between ribs such as in cardiac ultrasound.

Both curvilinear and phased array probes generate sector or "pie-shaped" images, narrower in the near field and wider in the far field, while linear probes typically generate rectangular images on the screen.

STRAIGHT LINEAR ARRAY PROBE

The straight linear array probe (Fig. 4-1*a*) is designed for superficial imaging. The crystals are aligned in a linear fashion within a flat head and produce sound waves in a straight line. The image produced is rectangular in shape (Fig. 4-1*b*). This probe has higher frequencies (5–13 MHz), which provides better resolution and less penetration. Therefore, this probe is ideal for imaging superficial structures and in ultrasound-guided procedures.

- Vascular access (central and peripheral)
- Evaluate for deep venous thrombosis
- Skin and soft tissue for abscess, foreign body
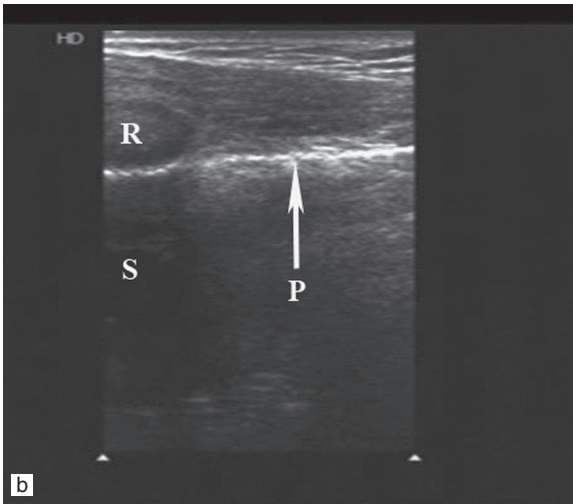- Musculoskeletal—tendons, bones, muscles

FIGURE 4-1 Straight linear array probe (*a*). Lung imaging using the straight linear array probe (*b*). Note the rectangular shape produced by the probe. R: rib, P: pleural line, S: rib shadow.

- Testicular
- Appendicitis in thin patients
- Evaluation of the pleural line for pneumothorax, interstitial fluid
- Ocular ultrasound
- Other procedures (arthrocentesis, paracentesis, thoracentesis, nerve blocks, etc)

CURVILINEAR ARRAY PROBE

The curvilinear array or convex probe (Fig. 4-2*a*) is used for scanning deeper structures. The crystals are aligned along a curved surface and cause a fanning
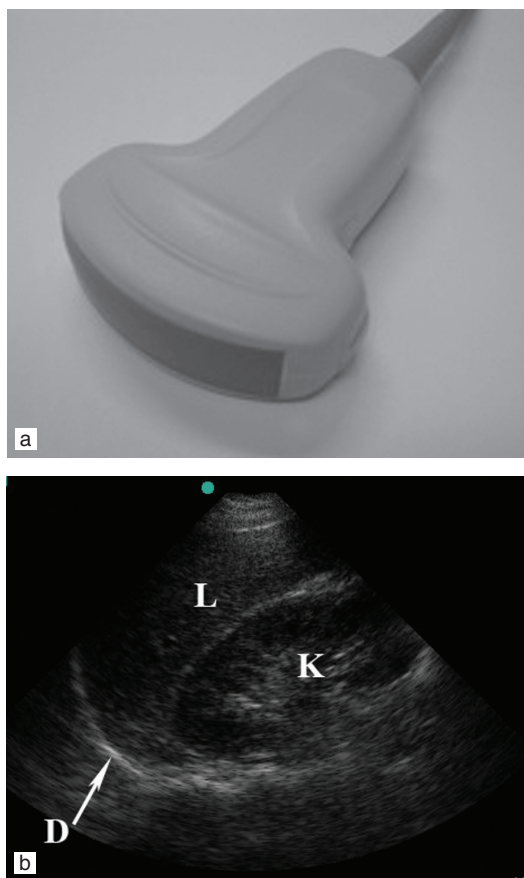
FIGURE 4-2 Curvilinear array probe (*a*). Right upper quadrant imaging using the curvilinear array probe (*b*). Note the sector shape produced by the probe. L: liver, K: kidney, D: diaphragm.

out of the beam, which results in a field of view that is wider than the probe's footprint. The image generated is sector shaped (Fig. 4-2*b*). These probes have frequencies ranging between 1 and 8 MHz, which allows for greater penetration, but less resolution. These probes are most often used in abdominal and pelvic applications. They are also useful in certain musculoskeletal evaluations or procedures when deeper anatomy needs to be imaged or in obese patients.

- Abdominal aorta
- Biliary/gallbladder/liver/pancreas
- Abdominal portion of FAST exam
- Kidney and bladder evaluation
- Transabdominal pelvic evaluation

ENDOCAVITARY PROBE

The endocavitary probe (Fig. 4-3a) also has a curved face, but a much higher frequency (8–13 MHz) than the curvilinear probe. This probe's elongated shape allows it to be inserted close to the anatomy being evaluated. The curved face creates a wide field of view of almost 180° and its high frequencies provide superior resolution (Fig. 4-3b). This probe is used most commonly for gynecological applications, but can also be used for intraoral evaluation of peritonsillar abscesses.

- Transvaginal ultrasound
- Intraoral (tonsillar) evaluation

PHASED ARRAY PROBE

Phased array probes (Fig. 4-4a) have crystals that are grouped closely together. The timing of the electrical pulses that are applied to the crystals varies and they are fired in an oscillating manner. The sound waves that are generated originate from a single point and fan outward, creating a sector-type image (Fig. 4-4b). This probe has a smaller and flatter footprint than the curvilinear one, which allows the user to maneuver more easily between the ribs and small spaces. These probes have frequencies between 2 and 8 MHz, but they usually operate at the
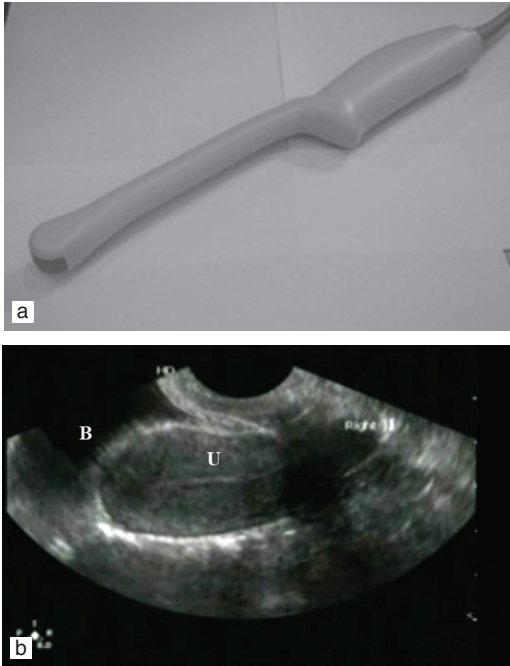

FIGURE 4-3 Endocavitary probe (*a*). Transvaginal ultrasound imaging using the endocavitary probe (*b*). This probe also produces a sector-shaped image, but a much wider field of view. U: uterus, B: bladder.
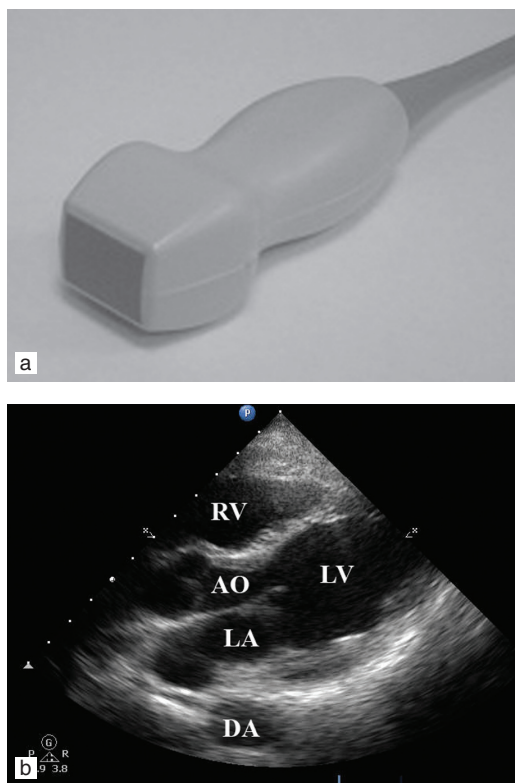
FIGURE 4-4 Phased array probe (*a*). Parasternal long-axis view using the phased array probe (*b*). Sound waves originate from a single point and fan outward, creating a sector-type image. RV: right ventricle, AO: aortic outflow, LV: left ventricle, LA: left atrium, DA: descending aorta.

higher end making them ideal for echocardiography. The phased array probe can also function at lower frequencies, which is useful for viewing the abdomen, pelvis, and for procedural guidance.

- Cardiac imaging
- Imaging between ribs in the flank or right upper quadrant
- May be used for transabdominal imaging if curvilinear probe not available

KNOBOLOGY

Although most ultrasound machines share some universal features, there is some variation in design between different manufacturers. It is important to become familiar with the particulars of the specific machine before scanning. The control panel of an ultrasound machine has various buttons and knobs that are used to adjust and record images.

ADJUSTING THE B-MODE IMAGE

B-mode, also known as basic, gray scale, or two-dimensional imaging, refers to the standard black and white image displayed on the ultrasound monitor.

Machine Presets Most machines have settings that will adjust an image based on the anatomy being scanned. These presets are programmed to optimize images based on certain gain and power settings, focal zones, frame rates, and other settings. For instance, the echocardiography setting will automatically default to a higher frame rate in order to capture better cardiac imaging. The correct preset should be chosen before scanning is initiated.

Depth The depth controls how much distance into the body the image displays in the far field. It is important to start out deep to not miss findings in the far field (Fig. 4-5a). Once the area of interest is identified and the far field has been surveyed, the depth can be decreased in order to focus in on the area of importance.
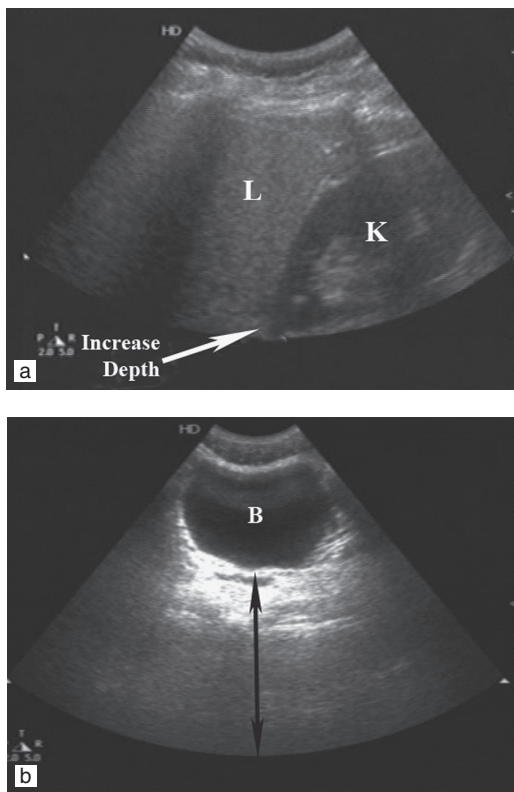
FIGURE 4-5 Right upper quadrant view illustrating too little depth (*a*). Note the liver (L) and kidney (K) appears shallow in this picture and are not fully imaged. Pelvic view (*b*) illustrating too much depth posterior to the bladder (B), and wasted space (black arrow).

When the depth is decreased, superficial structures will be magnified, which will improve resolution. Too much depth can be wasted space (Fig. 4-5*b*). Also, the larger the depth, the longer it takes for the machine to receive returning echoes, which can affect the quality and frame rate of the image display. Generally, depth should be adjusted to show the area of interest in the top two-thirds to three-quarters of the screen.

Gain   Gain adjusts how the machine "listens" for returning echoes. As the gain is increased, the strength of the returning echoes is amplified, which produces a brighter image. A decrease in gain will darken the image visualized on the monitor (Fig. 4-6*a*). Gain may be adjusted for the entire image (overall gain), or at depth, known as time-gain compensation (TGC). TGC may be set up as a column of sliding knobs, or may be adjusted with knobs for "near gain" and "far gain."

Appropriate gain is important for image quality, but too much gain can increase noise and wash out an image, making it appear too white on the screen (Fig. 4-6*b*). This error can obscure important findings, such as free fluid. This is a common mistake made by many novice sonographers, particularly behind a fluid-filled structure like the urinary bladder, where posterior acoustic enhancement brightens the image in the far field. Too little gain, particularly in an area in the middle of an image (such as when one of the TGC sliders is too far to the left) may be misinterpreted as an anechoic area of fluid. It is a good idea to check that the TGC sliders are in line prior to beginning the exam.

The gain on the machine should be set at a level that creates a clear image without appearing too bright or dark (see Fig. 4-2*b*). Many newer machines have an "image optimization" button that will automatically attempt to adjust gain appropriately throughout the image. It will help to darken the ambient lighting in the room to avoid using gain that is too high.

Zoom   The zoom function allows for the magnification of one area on the screen. The image appears larger, but the resolution of the magnified area does not change. Zoom generally works by selecting a square area, which can be sized and located on the screen by the user prior to zooming. This function is important when attempting to visualize a deep or small structure such as an intrauterine pregnancy or the common bile duct. The depth of an image should be optimized first before a sonographer zooms into a particular area.

Focus   The focus control optimizes the lateral resolution at a given depth. The best resolution of an object is found at the focal zone where the ultrasound beam is at its narrowest. Most monitors will display a small marking or arrow on the side of the screen indicating where the beam is focused. The focus is usually established for a specific application, but may need to be adjusted depending on what is being scanned. Focal zone is particularly important when trying to elicit shadowing from suspected gallstones.

Tissue Harmonics   When echoes are reflected off an object, they not only return at the fundamental frequency, but also at harmonic frequencies, which are at multiples of the fundamental frequency (2x, 4x, etc). These higher frequency waves experience less attenuation and less scatter and side-lobe artifact and may generate clearer images, particularly at the interface between fluid and tissue. Most machines will have a button called "tissue harmonic imaging" or THI, which will allow the transducer to use these harmonic frequencies. This imaging modality is used most commonly in cardiac applications.

Dynamic Range   Dynamic range refers to the range of echoes displayed and is expressed in decibels (dB). A high dynamic range is generally desirable as it will have a wider range of echo strength and will show more contrast, but the range may be reduced to minimize artifacts. Dynamic range is initially set based on the
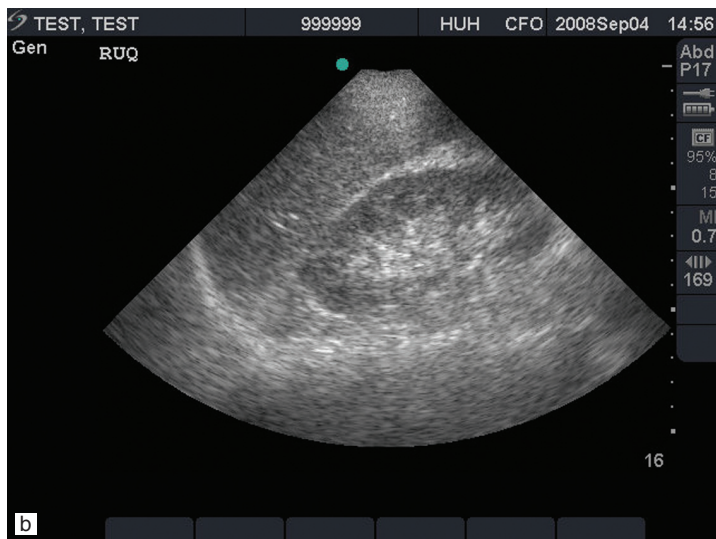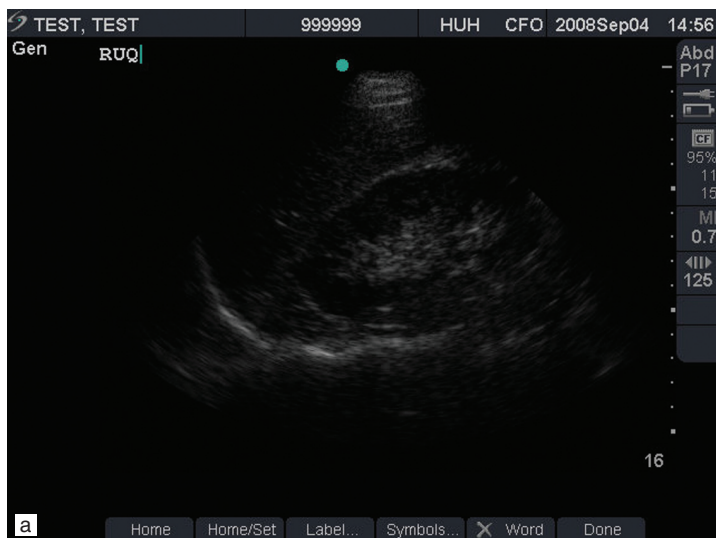
FIGURE 4-6 Right upper quadrant view demonstrating different gain levels. In (*a*) the image appears too dark and the gain needs to be increased. In (*b*) the image appears too bright and washed out which can obscure subtle findings such as free fluid. The overall gain needs to be decreased.

machine preset (ie, dynamic range for cardiac scanning is higher than abdominal scanning) but may be adjusted by the sonographer.

Frame Rate Dynamic or moving ultrasound is really just a series of still images displayed one after another to create motion. Frame rate refers to how many times per second a still image is displayed, measured in hertz (Hz) or frames per

second. A high frame rate (30–40 Hz) is important for echocardiography, as the heart is moving quickly. A lower frame rate may allow for better individual images but may appear choppy. Frame rate is typically maximized for the depth and image aperture selected (ie, frame rate will increase as the field of view is decreased) but may be adjusted on the machine to a lower rate if desired.

OTHER MODES

M-Mode (Motion-Mode)   M-mode is used to visualize things that are physically moving. The motion occuring in a one-dimensional scan line is displayed on the vertical axis over time on the horizontal axis (Fig. 4-7). It is used in conjunction with B-mode scanning and should not be confused with Doppler imaging. The M-mode cursor (a single line) is placed over the moving object on the B-mode image, and the M-mode button is pressed. This mode is most commonly used in the evaluation of cardiac valves and fetal heart activity. It is also useful in measuring the respiratory variability of the inferior cava and in the evaluation of the lungs for pneumothorax.

Doppler   Doppler uses the frequency shift of sound waves to measure velocity, typically of blood (though tissue Doppler may measure myocardial motion). The most commonly used modes of Doppler are color-flow Doppler (CFD), power or angio Doppler, and spectral Doppler (pulsed [PW] and continuous wave [CW]).

Color Doppler displays the movement toward the probe as red and away from the probe as blue (Fig. 4-8). The use of color flow is helpful when attempting to identify a blood vessel and differentiate it from other surrounding structures.

Power (angio) Doppler measures flow within an object, but not direction. It also relies on a frequency shift to detect the presence of flow, but displays it in one color, usually orange, and therefore does not differentiate between flow toward or
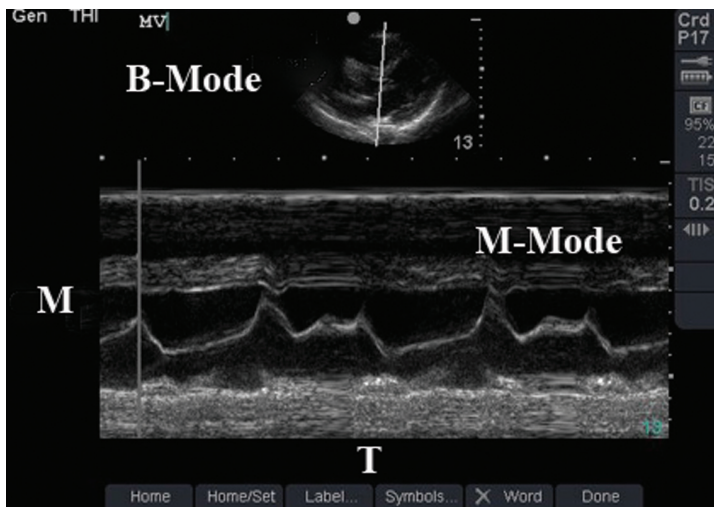

FIGURE 4-7 The use of M-mode in cardiac imaging. The upper image demonstrates a parasternal long-axis view of the heart seen in B-mode with the M-mode line placed across the mitral valve. The lower image depicts the motion (M) of the mitral valve on the Y-axis over time (T) on the X-axis.
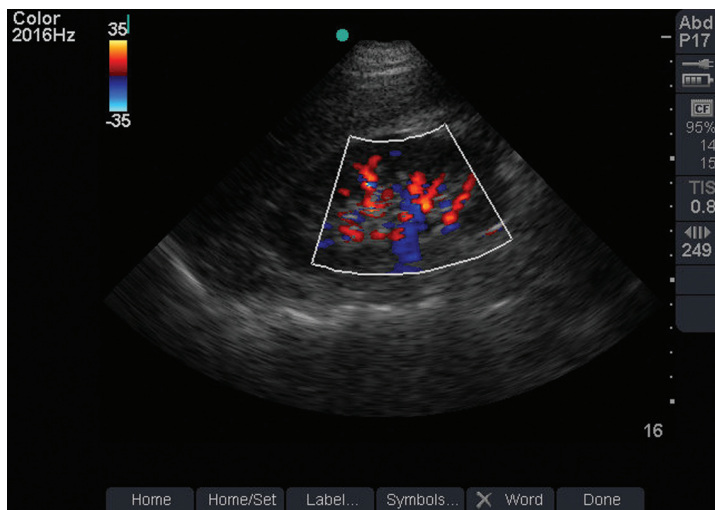
FIGURE 4-8 This image illustrates the use of color-flow Doppler in evaluating for renal blood flow. The red and blue colors represent flow toward and away from the probe, respectively.

away from the probe. It is more sensitive and less angle-dependent than color-flow Doppler at picking up low flow states, and therefore is useful for structures such as the testes. However, due to its sensitivity, small movements of the probe can create unwanted motion artifacts on the screen more commonly than other Doppler modes. Power Doppler is also useful in evaluating for urinary bladder jets in ruling out ureteral obstruction (Fig. 4-9).
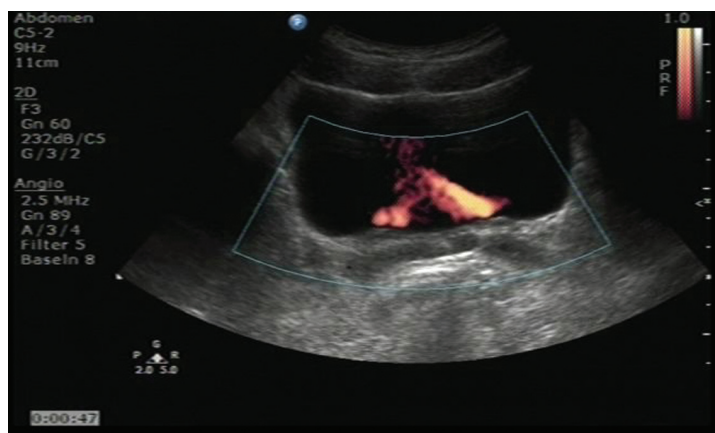

FIGURE 4-9 This image illustrates the use of power (angio) Doppler in evaluating for urinary jets within the bladder. Note the jets are present bilaterally, signifying no renal obstruction.
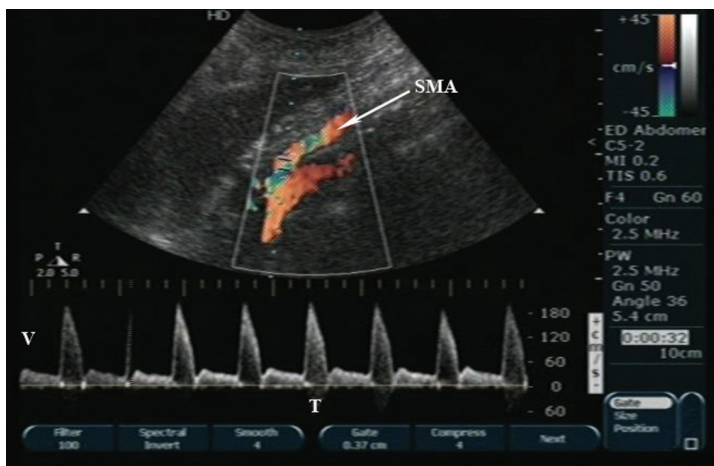
FIGURE 4-10 Pulsed-wave (PW) Doppler of the superior mesenteric artery (SMA). The image above shows the SMA with color flow. The PW Doppler calipers are placed over the blood flow within the lumen. The image below depicts the velocity (V) of blood flow on the Y-axis over time (T) on the X-axis.

Spectral Doppler displays velocity of flow on the X-axis against time on the Y-axis. Pulsed-wave Doppler (Fig. 4-10) allows the area of interest to be defined, but the maximum velocity is limited (the "Nyquist limit"). Continuous wave Doppler examines the maximum velocity along an entire scan line, and allows much higher velocity measurements, such as occurs in a stenotic valve (Fig. 4-11).

ADJUSTING THE DOPPLER IMAGE

Pulse Repetition Frequency (PRF) or Scale   Adjusting the PRF, sometimes labeled as the scale, adjusts the sensitivity of Doppler for flow velocity. A lower PRF will result in a lower scale, more sensitive for slower flows, but may cause more artifact (from "aliasing"). The scale will usually be displayed either on the side of the screen with corresponding colors for color and power Doppler, and along the Y-axis for spectral Doppler. On the lower end, the color Doppler scale may be as low as ~5 cm/s. Maximum scale for CW Doppler may go as high as 6 m/s.

Doppler Gain   Similar to the basic B-mode or two-dimensional image, gain may be adjusted for Doppler. Increasing Doppler gain will amplify returning signals, resulting in more color or a stronger spectral signal. As in B-mode imaging, too much gain will result in noise and artifact.

Baseline   Doppler can display flow either toward or away from the probe. Typically for color or spectral Doppler, the "zero" is in the center of the scale (or Y-axis). If you want to look only at the positive (or negative) flow, you can adjust the baseline up or down.

Wall Filter   Filter allows adjustment of the signal so that lower velocities up to a certain number will not be displayed, most applicable in color and power Doppler. A higher filter will reduce artifact but may limit visualization of lower flow.
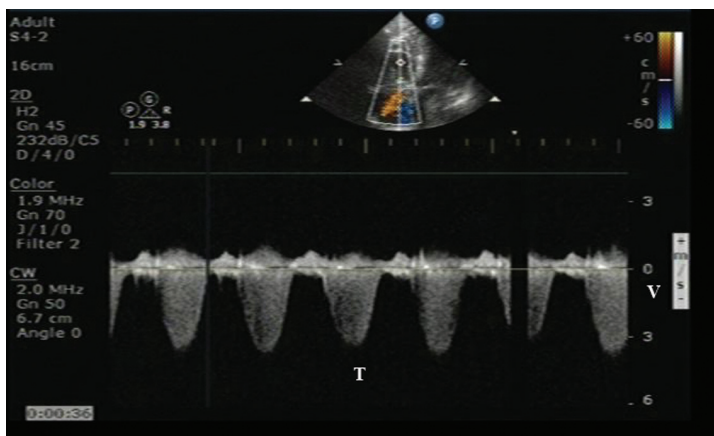
FIGURE 4-11 Continuous wave (CW) Doppler of the tricuspid valve (TV) in a patient with significant tricuspid regurgitation (TR). The image above shows an apical 4C view of the heart with the CW Doppler calipers placed over the TR flow. The image below depicts the velocity (V) of the TR on the Y-axis over time (T) on the X-axis. Note the wave produced by the Doppler tracing is depicted below the baseline, which represents blood flow away from the probe. CW Doppler is used in this situation due to its ability to pick up higher velocities, such as blood flow over turbulent valves.

MANIPULATING AND SAVING THE IMAGE

Freeze   The freeze button is used to create a still image on the monitor. This control captures a single frame from a dynamic image. Most machines capture several seconds of still images, allowing selection of a previous image after pressing the freeze button. After freezing the scan, the sonographer can add text, make measurements or calculations, save or print the image.

Calculations   Basic calculations, such as measurement, will be available on all images. Other calculations will be available based on the preset selected. For example, there are calculations specifically for fetal heart rate and gestational age in the obstetric setting. These calculations stress the importance of choosing the correct preset scanning mode.

Acquiring Images   Images may be captured for archival or export. Still images may be saved by freezing the image and then hitting the appropriate button (acquire, save, store, etc). A moving image or "cineloop" is a dynamic clip, typically of several seconds, captured by acquiring the image without freezing it.

Most machines now store images digitally on an internal hard drive that can then be transferred to a more permanent storage location, either wirelessly or by connecting the machine to a storage device or ethernet cable. It is also possible to record much longer videos using an external videotape or DVD recorder if desired.

The industry standard for image storage is DICOM (Digital Imaging and Communications in Medicine), which may be an extra option on a machine. A picture archival communication system (PACS) uses DICOM and is the gold standard for image archival and review, although there are many ways to transfer, store, and print images.

OTHER EQUIPMENT

COUPLING MEDIA

Sound travels much better through liquid than air, and something to couple the face of the probe to the tissue is essential in obtaining an image. Most commonly gel is used, but standoff pads and water baths may also be used.

Gel is a water-based coupling medium that is more comfortable to the patient when warmed. It may be placed on the patient directly or on the probe first and should be used generously to avoid contact artifacts. Sterile gel should be used in contact with a mucous membrane or open wound, or in sterile procedures. Sterile gel is commonly available in packets (such as "Surgilube") or in sterile probe cover kits.

Superficial structures can be difficult to scan due to echoes that appear in the near field as a result of reverberation artifacts produced by the transducer. A standoff pad can be placed in between the probe and the skin, which places the structure of interest at the focal zone. This improves the lateral resolution and image quality. These are commercially available or the songrapher can create one using a gel pad or intravenous (IV) fluid bag.

A water bath can also be used in the scanning of superficial structures in place of gel. The patient's body part, usually the hand or foot, is placed inside a basin of water. The probe is then placed on top of the water surface and the area of interest is scanned from above. The water bath improves the resolution of the image and is also useful in avoiding direct contact of the probe with the skin surface, therefore improving patient comfort.

PROBE COVERS

Probe covers or sheaths protect probes from contamination and the patient from potential infection. Sterile probe covers are recommended for central line access, joint aspiration, and other procedures that have infection risks. Probe covers are also used for procedures that are not sterile, but involve exposure to mucous membranes, such as endovaginal or peritonsillar abscess evaluation. In these cases, a nonlatex condom should be used. Other nonsterile procedures that may benefit from probe covers include peripheral IV access and incision and drainage of an abscess. The use of a Tegaderm (or other cover such as a glove) can help protect the probe from contamination in these situations. Gel is required on both the inside and outside of any cover.

PROBE CLEANING

Probes and probe cords should be cleaned both before and after use. Any visible contamination can be removed by rinsing the probe using water and soap. Commercially available sprays are appropriate for basic disinfection. High-level disinfection (HLD) is a more thorough cleaning method that is often recommended for cleaning endocavitary probes after use, although the necessity of this level of cleaning when appropriate cleaning and probe covers are used is debated. HLD involves the use of a prolong soak in chemicals (eg, Cidex) requiring a designated area with ventilation/hoods.

PERIPHERAL INTRAVENOUS CATHETERS

Typical IV catheters for peripheral access are 1¼ in in length, and may infiltrate when used in deeper vessels identified by ultrasound. It is recommended that peripheral IVs be at least 1¾ in to over 2 in for ultrasound-guided peripheral access.

HAND TOWELS

Small cloth towels, kept with the machine, are helpful in cleaning gel off of patients, as well as probes and the machine.

Additional Reading

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