SCROTAL ULTRASOUND
Focusing on the principles and practice

By Bruce R. Gilbert, MD, PhD

An understanding of the testicular anatomy and the fundamental principles of ultrasound are prerequisites of an optimal scrotal exam. These essentials and a systematic scanning protocol ensure patient safety and guide the urologist in selecting the best transducer and optimizing image quality.

S
crotal ultrasound (US) is a routine—and often essen-
tial component—of the evaluation of the male patient presenting with scrotal symptoms. This noninvasive procedure provides urologists with real-time information that is often invaluable in providing a rapid and accurate diagnosis. When performed in a urologist’s office, it can save patients time and money.

Urologists are uniquely qualified by training and experience to perform, interpret, and document scrotal US studies, and should maintain a high degree of proficiency in these skills. The primary goal of this article is to provide practicing urologists with an overview of the principles and practice of office scrotal US. Initial proficiency in scrotal US requires “hands-on” training under the mentorship of an experienced sonographer, which often occurs during residency. Classes for maintaining and updating these skills are available through the American Urological Association (AUA), various academic training programs, and US equipment manufacturers. In addition, many excellent educational resources are available online.

RELEVANT EMBRYOLOGY AND ANATOMY
A basic understanding of the embryologic development of the scrotal structures and the scrotal blood supply helps guide the interpretation of certain abnormalities in scrotal US.

Developmental anatomy.
In the 3-week-old embryo, primordial germ cells in the wall of the yolk sac close to the at-
tachment of the allantois migrate along the wall of the hindgut and the dorsal mesentery into the genital ridge. In the 5-week-old embryo, the 2 excretory organs (the pro-
ephros and mesonephros systems) regress, leaving only the mesonephric duct. The metanephros (adult kidney) forms from the metanephric diverticulum (ureteric bud) and the metanephric mass of mesoderm. The ureteric bud develops as a dorsal bud of the mesonephric duct near its in-
sertion into the cloaca.

At 7 weeks, the indifferent embryo has 2 parallel pairs of genital ducts: the mesonephric (Wolffian) and the para-
mesonephric (Müllerian). By week 8, the developing fetal

tests produces at least 2 hormones. The first, known as Müllerian-inhibiting substance or factor (MIS, MIF) or anti-Müllerian hormone (AMH), is pro-
duced by the fetal sertoli cells and suppresses unilater-
al development of the paramesonephric duct. The
other, testosterone, stimulates development of the
mesonephric duct into the male genital tract. Vestigial
remnants (Figure 1) often can be visualized sono-
graphically. The appendix of the testis persists as a
vestigial remnant of the paramesonephric duct, while
the appendix of the epididymis persists as a vestigial
remnant of the mesonephric duct.

In the 7-week-old embryo, the testes are positioned in the dorsal abdominal wall. At about 28 weeks, the process vaginalis and testis begin to pass through the inguinal canal with facial coverings from the abdomi-
nal wall. These coverings become the coverings of the spermatic cord and testis. The scrotum contains 2 compart-
ments divided by a septum with multiple facial layers be-
nath the skin and dartsos facia. The primary components of each compartment include a testis, an epididymis, and a spermatic cord (Figure 2). The latter contains the ductus deferens and arterial and venous vessels (pampiniform plexus). Each testis is covered by a thick, fibrous, connec-
tive tissue layer (tunica albuginea) and 2 thinner connective
tissue layers formed when the process vaginalis closes—a visceral layer and the parietal tunica vaginalis—creating a cavity that normally contains a small amount of fluid.

When this cavity contains more than the physiologic amount of fluid (1–2 mL), a hydrocele is present. When
blood collects in this cavity or in areas outside the parietal
vaginalis, it constitutes a hematocoele.

The scrotal blood supply. The scrotal structures receive their blood supply from 3 principal sources:

• the testicular artery (arising from the aorta and supplying the testis),
• the cremasteric artery (a branch of the inferior epigastric artery supplying the scrotal sac and coverings of the sper-
matic cord), and
• the deferential artery (arising from the superior vesical ar-
tery and supplying the vas deferens and epididymis).

The veins draining the testsis exit at the mediastinum, where they join the veins draining the epididymis to form the pampiniform plexus. The cremasteric plexus, which drains blood primarily from extratesticular structures, lies posterior to the pampiniform plexus at the superior por-
tion of the testis. The right testicular vein joins the inferior vena cava below the level of the right renal vein, while the left testicular vein drains into the left renal vein.

Along the length of the spermatic cord, the vascular sup-
ply is covered by the cremasteric muscle and loose connec-
tive tissue, and is in close approximation to nerves, lym-
phatics, and the vas deferens.

HOW US WORKS
Attenuation, resolution, and the biologic effects of US are all related to the physical principles of the sound wave. Sound waves are considered longitudinal pressure waves.
because the particles in the medium move in the same di-
trection that the sound is trav-
eling. Because the particles vi-
brate back and forth, the wave is also considered mechanical
in nature. These concepts are important when considering the move-
ment of a sound wave through tissues.

Although human hearing is in the frequency range of 20 Hz to 20,000 Hz (cycles/second), imaging transducers for US typically operate in the range of 2 to 15 MHz (megahertz/second). Because it is important to keep in mind that frequency and wavelength are inverse-
ly related through their relationship with velocity (wherein Velocity = Freq-
yency x Wavelength).

Two types of US waves can be gen-
erated:

• Continuous wave US uses 2 transduc-
ers—1 for transmitting and 1 for re-
ceiving—and is “on” all the time. It is not practical for imaging but is very use-
f ul for determining the speed and direc-
tion, but not the depth, of blood flow.
• Pulsed wave US, used for imaging, uses a single transducer to generate and receive. After a few cycles are gen-
erated, the transmission stops and waits for the signal to inter-
cet a tissue “reflectors” and return a portion of the sound wave to the transducer. The transducer then receives the pulses and analyzes the returning signal (echo).

**DOCUMENTATION AND BENCHMARKS**

Proper documentation of scrotal US findings requires correct orientation of the testis and appropriate labeling of the images. The com-
mon terms used in scrotal US are axial, sagittal, coronal, superior, and inferior; in the transverse orientation, the terms anterior, poste-
rior, medial, and lateral are used. **Echogenicity.** For most US studies, the liver is typically used as the bench-
mark for echogenicity. In scrotal US, however, it is also important to com-
pare the echogenicity of the 2 testes.

A variety of terms are used to de-
scribe the relative echogenicity of the testes as compared with that of the ref-
ence, including hypoechoic (darker and black on US), hyperechoic (brighter and white on US), and isoechoic (simi-
lar to the reference on US). High water content makes tissue appear hypo-
echoic, while high fat content makes tissue appear hyperechoic. Additional qualities like anechoic (without echo), homogenous (of uniform echogenicity), and heterogeneous (of mixed echogenicity) are used to convey additional quantitative information about the composition of the struc-
ture being imaged.

**SIGNAL TERMINOLOGY IS KEY**

It is important to understand the variety of terms used to de-
scribe the transmitted signal (Figure 3) because these vari-
ables can often be adjusted by the sonographer to improve the quali-
ty and reliability of the image.

**Pulse repetition frequency (PRF).** The PRF is the number of pulses oc-
curring in 1 second (expressed in kHz). In clinical practice, the PRF is the most important variable to under-
stand, especially when using color Doppler (CD) US. At a given PRF, the maximum Doppler frequency that can be measured (without distortion) is equal to 1/2 the PRF (also known as the Nyquist limit). This is a funda-
mental limitation of all pulse-wave systems. If the velocity of the blood flow and the beam/flow angle com-
bine to give a Doppler frequency ex-
ceeding 1/2 the PRF, aliasing (Figure 4) will occur.

In a pulsed Doppler system, there must be a sufficient time interval for the sampling pulse to reach the reflec-
tor and make its way back to the transducer before a sec-
ond pulse is generated. If the second pulse is generated be-
fore the first pulse is re-
Received, the 2 pulses are un-
able to be differentiated and ambiguity occurs. Also, as the depth of the reflector in-
creases, a longer time inter-
val is also required before the second pulse is generated. Therefore, the maximum Doppler frequency that can be measured decreases with increasing depth.

Low PRFs are used to study low flow velocities (such as venous flow, varico-
celeal flow, and other slow flowing structures). High PRFs are used to examine high flow velocities. When using low PRFs, aliasing will occur when high flows are encountered. Conversely, low flow velocities may be misrepr-esented when high PRFs are being used.**

**Pulse repetition period (PRP).** The PRP is the time from the start of 1 pulse to the start of the next (ex-
pressed in ms).

**Spatial pulse length (SPL).** The SPL is the space occupied by 1 pulse (the wavelength times the number of cycles in the pulse, ex-
pressed in mm).

**Pulse duration (PD).** The PD is the time it takes for 1 pulse to occur (ex-
pressed in µs).

**Amplitude.** The size of the sound wave (expressed in units of pressure, Mpa).

**Intensity.** This is the concentration of energy in the sound wave (equal to the square of the amplitude, expressed in mW/cm²).

**Propagation speed.** This is the speed at which the US wave moves through tissues in the body. When US systems measure the time it takes for an echo to return (to calculate the depth of the ob-
ject of interest), they assume a constant propagation speed of 1.544 m/s. However, because propagation speed actually varies with tissue density (Table 1), a misregistration artifact oc-
curs, producing a US image that fails to represent the actual anatomy.

**RESOLUTION, IMPEDANCE, AND REFLECTION**

The terms resolution, impedance, and reflection are important in describing image quality, understanding why res-
olution changes with transducer fre-
quency, and how the sonographer can improve the quality of the image by making adjustments in equipment set-
tings.

**Resolution.** (Spatial or detail) resolu-
tion includes axial (longitudinal), lat-
eral, and elevation resolution. **Axial resolution** is the ability to sepa-
ration of 2 objects that are next to each other (side-by-side). Be-
cause lateral resolution is determined by the width of the beam in the direc-
tion of sound wave propagation, im-
age quality is the best at the focal zone (the narrowest point of the beam). **Elevation resolution** is determined by the width of the beam perpendicular to the direction of motion. Because the perpendicular direction is deep to the scan plane, a slice thickness artifact can occur. A good example is when echoes are seen in an anechoic struc-
ture (such as a cyst) because the width of the perpendicular beam is greater than that of the structure of interest. **Temporal resolution**, the ability to identify the position of a moving structure at a particular point in time, is directly related to the number of im-
gages generated by the US system per second (the frame rate). The goal is to

**TABLE 1 Speed of US through various body tissues**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Speed of US (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>330 (0.33 mm/µs)</td>
</tr>
<tr>
<td>Lung</td>
<td>500 (0.50 mm/µs)</td>
</tr>
<tr>
<td>Fat</td>
<td>1,450 (1.45 mm/µs)</td>
</tr>
<tr>
<td>Brain</td>
<td>1,520 (1.52 mm/µs)</td>
</tr>
<tr>
<td>Liver</td>
<td>1,550 (1.55 mm/µs)</td>
</tr>
<tr>
<td>Kidney</td>
<td>1,560 (1.56 mm/µs)</td>
</tr>
<tr>
<td>Muscle</td>
<td>1,580 (1.58 mm/µs)</td>
</tr>
<tr>
<td>Bone</td>
<td>4,000 (4.00 mm/µs)</td>
</tr>
</tbody>
</table>
as the bladder and kidneys). Also, because the strongest echo returns to the transducer from perpendicular or specular reflectors, the sonographer may need to adjust the angle of incidence to get the best image.

Advancements in technology—including multiple bandwidth transducers and electronic focusing—have greatly simplified “knobology” and limited the need for multiple machine adjustments and for repositioning the probe during US exams.

WHY AND WHEN ARTIFACTS OCCUR

A US artifact occurs when an anatomic structure is incorrectly represented by the image—there is either an error in the location, the echogenicity, or the movement of the object of interest that may cloud image interpretation. Artifacts are not necessarily the result of sonographer or equipment malfunction, but are often related to assumptions made regarding the physical laws of sound—which may not always hold true. These include the beliefs that:

- a specular (perpendicular) reflector is always present;
- scattering does not occur; and
- sound travels at 1,540 m/second in water.

However, some assumptions are not always true, for example:

- a structure poorly attenuates or reflects, causing an increase in the amplitude of echoes behind the structure.
- a strong reflector produces a second, smaller echo at the transducer due to the partial reflection of a returning echo at the transducer.
- echoes outside the structure are therefore included in the image.
- echoes from the vessel wall are reflected back to the receiver.
- range ambiguity is always present;
- a specular (perpendicular) reflector is always present;
- range ambiguity is always present.

Since vessel wall movement is the primary cause of motion artifact, the term “wall” filter has been used. Unfortunately, this filter can also limit the ability to measure low flow velocities. Thus, the sonographer may need to adjust the filter settings. There are several types of Doppler US (Figure 11): Continuous wave Doppler (CWD) uses 2 crystals (1 receives and 1 transmits). Although it can measure high velocities, the position (or depth) at which the velocity is measured is unknown. It cannot be used to produce color flow images. CWD is not used for scrotal imaging, but is sometimes used for scrotal imaging because it produces high velocities.
Color power Doppler (CPD) encodes the power in the Doppler signal in color by displaying the total integrated signal instead of the mean Doppler frequency shift. The major limitation of CPD is that it does not provide directional information. However, it is often more sensitive than CD in detecting lower blood flow speeds. Spectral Doppler (SD), which examines flow at a single site, is often used in combination with CD. It provides superb temporal resolution allowing for detailed analysis of the waveform including the calculation of velocities and indices.

The Resistive Index (RI) is a frequently used CD index. It is easily calculated from measurements of the peak systolic velocity (PSV) and the end diastolic velocity (EDV), where $RI = \frac{PSV}{PSV-EDV}$ is the Resistive Index. The acronym ALARA (As Low As Reasonably Achievable) is often used in association with imaging modalities. During US, this is accomplished by using procedures and equipment designed to limit the mechanical and thermal effects of US, including:

- use of the lowest power setting possible;
- limiting the time the transducer is active;
- proper transducer selection (higher frequency transducers require greater intensity to “see” at greater depth); and
- implementing “knobology” to appropriately adjust the PRF, focus, power, and pulse length.

It is also extremely important that all equipment receives routine maintenance and that transducers are disinfected before and after use. Each office should develop a standard operating procedure manual that states the policy and the documentation required to insure compliance. Manufacturers’ guidelines must be followed. Any patient complications or equipment malfunctions should be documented and follow-up actions recorded.

**PATIENT SAFETY**

US has an excellent safety record. The American Institute of Ultrasound in Medicine has stated and reaffirmed that “No confirmed biological effects on patients or instrument operators caused by exposure at intensities typical of present diagnostic US instruments have ever been reported.” However, because US propagates through tissue, there is the potential for tissue damage through thermal heating and nonthermal phenomena (such as cavitation). The acronym ALARA (As Low As Reasonably Achievable) is often used in association with imaging modalities. During US, this is accomplished by using procedures and equipment designed to limit the mechanical and thermal effects of US, including:

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**PHYSICAL ENVIRONMENT... THE FENG SHUI OF US**

The US exam room should provide comfort and privacy for the patient. Simple measures, such as providing a space heater to warm the room and using a gel warmer, are greatly appreciated by patients and can even improve the quality of the exam. The room should be spacious enough for the patient and all necessary equipment. It is important that there be adequate room for interpreting and documenting the images and for secure storage of permanent images and written reports. Electronic medical record systems can easily store images, facilitating the documentation of US exams.

**THE NORMAL SCROTAL US EXAM**

The adult testis is approximately 4 to 5 cm long, 3 cm wide, 2 to 3 cm in the anterior-posterior (AP) dimension, and typically between 20 and 30 mL in volume. It is a smooth ovoid gland that exhibits homogeneous echogenicity. The 250 conical lobules, composed of seminiferous tubules, converge at the mediastinum to form the rete testis.
tion. The caput epididymis is often, but not always, more echogenic than the testis and coarser in appearance (Figure 12, top right). The smaller corpus epididymis can be seen as a hypoechoic structure containing multiple echogenic linear structures representing the coiled epididymal tubule.7 In men who have undergone a vasectomy or who are experiencing epididymitis, it is often less echogenic than the testis (Figure 12, bottom).

**SCANNING PROTOCOL: TIPS AND TECHNIQUE**

The key to performing a complete and thorough scrotal exam is to develop a protocol and follow it—on every scan. My approach, presented here, provides a foundation that others may vary according to their experience and preferences.

**Patient preparation.** The patient’s scrotum should be supported. While towels or drapes are often used, having the patient place his legs together actually provides the best support. A towel or drape should be placed over the base of the phallus. The patient can be asked to hold the tip of his phallus to prevent it from obscuring the field.

**Transducer selection.** A high frequency (7.5-10 MHz) transducer should be used for scrotal scanning. Broad bandwidth transducers allow for multiple focal zones, eliminating the need for adjustment during the examination. Multiple frequency transducers allow the transducer to be set at one of several distinct frequencies. A linear array probe with a “footprint” able to measure the longitudinal length of tests is ideal. While a curved array probe can be used for large tests and to compare the tests, the frequency is usually lower, resulting in a less detailed image. Color and spectral Doppler are becoming essential elements of scrotal US because they provide documentation of normal testicular blood flow and paratesticular findings.

**Survey scan.** The images that should be obtained are listed in Table 4. Begin with a longitudinal survey scan of the scrotum, progressing medial to lateral to get an overall impression of the testis and paratesticular structure. The standard orientation of the image should be with the superior pole to the left and the inferior pole to the right. If the tests are larger than the footprint of the transducer, be sure to get views of the superior and inferior portions of the tests including the epididymis in those regions. Measure the long axis at the mid-tests together with the AP measurement.

Now switch to the transverse view by rotating the transducer 90°. The standard orientation for the right tests is to have the lateral aspect to the left and the medial aspect to the right. Conversely, for the left tests, the lateral aspect should be to the right and the medial aspect to the left. Using the mid-tests as a starting point of the survey scan, proceed first towards the superior pole then back to the to mid-tests before scanning to the inferior pole. Measurements of width and AP dimensions are taken and documented at the mid-tests. If the equipment being used has split-scan capabilities, comparative views of echogenicity and blood flow can easily be made and documented.

The use of CD imaging should be considered an integral part of the scrotal US exam. Many inflammatory, neoplastic, and benign conditions have characteristic flow patterns that can assist in diagnosis. Several of these test continues on page 22
PROPER DOCUMENTATION

The written report and archived images are a reflection of the quality of the examination. The old adage “If it’s not documented, it wasn’t done” should guide the sonographer in developing a quality report. The static images obtained during the evolving US exam should represent the sonographer’s impression of the findings. If electronic storage space is available and the equipment allows, video clips, which better represent findings, can be saved. A quality report can aid in diagnosis, and is therefore in the best interest of our patients.

Figure 13 provides an example of a report form for scrotal US. In addition to the measurements and anatomic findings of the exam, it is essential to include patient identification information, the exam date, and the indications for performing the exam. The report should be signed by the physician who performed the exam.

Images should be attached to the report. Each image should include the date, the time, patient identification, and the transducer used and its frequency. The area of interest should be clearly identified. The orientation and measurements should be clearly labeled along with the pertinent anatomy and any abnormalities.

REFERENCES