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 essential—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 attachment 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 pronephros and mesonephros systems) regress, leaving only the mesonephros. The mesonephros (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 insertion into the cloaca. At 7 weeks, the indifferent embryo has 2 parallel pairs of genital ducts: the mesonephric (Wolffian) and the paramesonephric ( Müllerian). By week 8, the developing fetal testes produce at least 2 hormones. The first, known as Müllerian-inhibiting substance or factor (MIS, MIF) or anti-Müllerian hormone (AMH), is produced by the fetal sertoli cells and suppresses unilateral 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 sonographically. The appendices of the testes persist as a vestigial remnant of the paramesonephric duct, while the appendices of the epididymis persist 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 abdominal wall. These coverings become the coverings of the spermatic cord and testis. The scrotum contains 2 compartments divided by a septum with multiple facial layers beneath the skin and dartos fascia. 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, connective 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 hematiccele.

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 spermatic cord), and
• the deferential artery (arising from the superior vesical artery and supplying the vas deferens and epididymis).

The veins draining the testes 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 portion of the testis. The right testicular vein joins the inferio 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 supply is covered by the cremasteric muscle and loose connective tissue, and is in close approximation to nerves, lymphatics, 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-
rection that the sound is travel-
ing. Because the particles vi-
brate back and forth, the wave is also considered mechanical
in nature. These concepts are
important when considering the movement of a sound wave through the body.

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 (cycles/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-
ency × Wavelength).

Two types of US waves can be gen-
erated:
• Continuous wave US: This uses 2 transdu-
cers—one for transmitting and 1 for re-
ceiving—and is “on” all the time. It is not practical for imaging but is very use-
ful 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-
cercept a tissue interface and then re-
turn a portion of the sound wave to the transducer. The transducer then receives and analyzes the returning signal (echo).

**DOCUMENTATION AND BENCHMARKS**

Proper documentation of scrotal US findings requires correct orientation of the
image to ensure that the appropriate labeling of the images. The com-
mon terms used in scrotal US in the longitudinal (sagittal)
orientation include anteri-
or, posterior, superior, and inferior; in the transverse
orientation, the terms anterior, poste-
orier, 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
testis as compared with that of the ref-
ference, 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 hypoe-
choic, while high fat content makes tissue appear hyperechoic. Additional
qualities like anechoic (without echo), heterogeneous (of mixed echogenicity), and heterogeneous (of mixed echogenicity) are used to convey addi-
tional qualitative information about the

**RESOLUTION, IMPEDANCE, AND REFLECTION**

The terms resolution, impedance, and reflection are important in describing
image quality, understanding why res-
dolution 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-
rately identify 2 objects, one in front of the
other, in the direction of the propa-
gating sound wave. Because the axial resolution is equal to 1/2 the SPL.
axial resolution increases as the SPL is re-
duced (by reducing the wavelength
or the number of cycles in the pulse).
A reduction in the wavelength (by increasing the frequency) or the
PRF therefore results in improved axi-
al resolution.

• Lateral resolution is the ability to dis-
criminate between 2 objects that are
next to each other (side-by-side).
Because 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).
• Axial 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
determine the duration of a moving
structure at a particular point in time,
is directly related to the number of
images generated by the US system per
second (the frame rate). The goal is to
optimize the frame rate to maxi-
mize temporal resolution.

**Impedance and reflection.** The qua-
lity of the echoes produced by an US wave reflecting off of a tissue interface
is based on the acoustic im-
pedance of the tissues (their resist-
ance to sound waves, related to the
density of the tissues and the propa-
gation speeds within the tis-

Table 1. Speed of US through various body tissues

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Speed of US (m/s)</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>

**SPL is the space occupied by 1 square meter of energy contained in the sound wave, expressed in Decibels (dB).**

**PD is the duration of the pulse, expressed in ms.**

**PRP is the time from the start of 1 pulse (the wavelength times the number of cycles in the pulse, expressed in mm).**

**Pulse duration (PD).** The PD is the time it takes 1 pulse to occur (expressed in µs).**

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

**Intensity.** 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 tis-
esues 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 1,540 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.

**Scrotal Ultrasound**

The ultrasound waveform descriptors

**PRF per unit time (5)**

**TIME**

**DISTANCE**

**SPL**

**PR**

**PD**

**Graphical representation of ultrasound waveform descriptors.**

**FIGURE 4**

**Aliasing**

This artifact occurs when Doppler frequency exceeds 1/2 the PRF (the Nyquist limit).
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 (how the transducer is angled) throughout the examination 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;
- the beam width is always equal to the diameter of the object of interest; and
- sound travels at 1,540 m/second in all tissue.

Several artifacts commonly seen in scrotal US actually aid in diagnosis. Common artifacts that arise with 2D (real-time) US are listed in Table 2, and those that occur with CD US are listed in Table 3.

Table 2: Artifacts in 2D US

<table>
<thead>
<tr>
<th>DISTORTION</th>
<th>Geometric (ghost, split)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signal intensity (edge shadow)</td>
</tr>
<tr>
<td>DISPLACEMENT</td>
<td>Mismatched reflection</td>
</tr>
<tr>
<td></td>
<td>Beam geometry (blurring, slice thickness)</td>
</tr>
<tr>
<td>SHADOWING</td>
<td>Angle of incidence</td>
</tr>
<tr>
<td></td>
<td>Reflection (edge shadowing)</td>
</tr>
<tr>
<td></td>
<td>Reflection (diffuse, edge shadow, specular)</td>
</tr>
<tr>
<td></td>
<td>Attenuation</td>
</tr>
<tr>
<td>REVERBERATION</td>
<td>Comet tail/ring down</td>
</tr>
<tr>
<td></td>
<td>System noise</td>
</tr>
<tr>
<td></td>
<td>Mirror image</td>
</tr>
<tr>
<td></td>
<td>Pseudomass</td>
</tr>
<tr>
<td></td>
<td>Reflection</td>
</tr>
</tbody>
</table>

Table 3: Artifacts in color flow US

| ALIASING         | Wrap around |
|                 | Color |
| FLOW DETECTION   | Directional ambiguity |
|                 | False color modulation |
| FLOW VELOCITY    | Wall filter |
|                 | Spectral broadening |
|                 | Gain setting |
| MOTION           | Vascular |
|                 | Flash |
| COLOR MODULATION | Uniform |
|                 | Color gap |
|                 | Color noise |
| REVERBERATION    | Reflection |
| DISPLACEMENT     | Range ambiguity |

Acoustic shadowing is seen when a structure strongly attenuates or reflects, causing a decrease in the amplitude of echoes behind the structure. Testicular calcifications such as those occasionally seen with microlithiasis (Figure 5) can produce this artifact, although it is better visualized with larger calcific densities. Acoustic enhancement is seen when a structure poorly attenuates or reflects, causing an increase in the amplitude of echoes behind the structure. Benign cystic structures such as epididymal cysts (Figure 6) produce this artifact. In fact, acoustic enhancement, a smooth circumscribed outer boundary, and an anechoic center are the diagnostic criteria for such cysts.

Reverberation artifact occurs when the partial reflection of a returning echo at the transducer due to a strong reflector produces a second, a third, or additional echoes that appear deeper on the display where, in fact, there are no additional reflectors. This occurs, for example, when imaging a testicular prosthesis (Figure 7).

An edge artifact is identified by a linear anechoic band, which is produced by phase cancellation effects at curved interfaces. This is often seen when imaging the caput epididymis (Figure 8). The slice thickness artifact occurs when the width of the beam perpendicular to the scan plane is larger than the structure of interest. Echoes outside the structure are therefore included in the image. This is often seen in patients with a large hydrocele, when echoes are produced in an anechoic structure (Figure 9). This artifact can often be reduced by narrowing or refocusing the beam.

Doppler US

This modality has evolved to become an important component of the scrotal US examination. The physical principle of interest in color flow US (which uses the Doppler principle to characterize “blood flow”) is that of the Doppler shift—the change in frequency caused by motion between the US beam and the receiver. The angle of incidence between the US beam and the estimated direction of flow (Figure 10, left) is known as the Doppler angle. Doppler US accurately measures velocity (the speed and direction of movement) only at Doppler angles of 0° and 180°.

Figure 5: Acoustic shadowing

This artifact occurs when a structure (in this case, testicular microlithiasis) strongly attenuates or reflects, causing a decrease in the amplitude of echoes behind the structure.

Figure 6: Acoustic enhancement

This artifact occurs when a structure (in this case, an epididymal cyst) poorly attenuates or reflects, causing an increase in the amplitude of echoes behind the structure.

Figure 7: Reverberation artifact

This artifact occurs when a strong reflector (such as this testicular prosthesis) causes a partial reflection of the returning echo at the transducer, producing additional (phantom) echoes.

Figure 8: Edge artifact

This linear anechoic band, often seen when imaging the caput epididymis, is produced at curved interfaces by phase cancellation effects.

Figure 9: Slice thickness artifact

This artifact, often seen in patients with a large hydrocele, occurs when the width of the beam perpendicular to the scan plane is larger than the structure of interest so that echoes outside the structure are included.

Figure 10: Reverberation artifact

This linear anechoic band, often seen when imaging the caput epididymis, is produced at curved interfaces by phase cancellation effects.

“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 in adult cardiac scanners to measure high velocities in the aorta. **Pulsed wave Doppler (PWD)** allows the operator to position a sample gate (an electronically steerable box or guide) within a vessel where Doppler shifts and velocity information can be obtained. PWD is used to provide data for CD, color power Doppler, and spectral Doppler.

**Color Doppler (CD)** converts Doppler shifts into colors and then superimposes them on a 2D image. CD involves many sample gates positioned at several depths along multiple scan lines. CD gives velocity information (speed and direction). Flow moving towards the scan head is represented at the top of the color bar, while flow moving away from the scan head is represented at the bottom of the color bar. CD has several limitations (Table 3):²

- **There is a tendency for noise to overwhelm the flow signal if the gain is too high or the threshold too low.** This can muddle the image, making it difficult to interpret.
- **Results are dependent on proper alignment of the transducer.**
- **Aliasing is a common artifact with pulsed wave Doppler, in which high velocity signals appear negative (Figure 9).**

**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.³ 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 $RI = (PSV-EDV)/PSV$. RI values of 0.7 and 0.5 are considered normal in the spermatic cord and intratesticular arteries, respectively.

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. From 8 to 12 efferent ductules connect the rete testis to the head (caput or globus major) of the epididymis, forming a single ductus epididymis. The septa and mediastinum testes may appear as linear echogenic areas on US (Figure 12, top left). The adult epididymis is 6 to 7 cm long and courses posteriordorsal to the testis with the head (caput); measuring 10 to 12 mm, the body (corpus) measuring 2 to 4 mm, and the tail (cauda) about 2 to 5 mm in greatest dimension.
The following images should be saved as part of the permanent record:

Longitudinal (sagittal) view of left mid-testis
- Width and AP measurement
- Measurement of body of epididymis

Longitudinal (sagittal) view of right mid-testis
- Width and AP measurement
- Measurement of body of epididymis

Longitudinal (sagittal) view of caput epididymis (split-screen image of right and left sides)
- Comparison of echogenicity
- Measurement of width

Longitudinal (sagittal) view of cauda epididymis (split-screen image of right and left sides)
- Comparison of echogenicity
- Measurement of width

Transverse view of both testes (either single split-screen image or image of each side individually)
- Compare echogenicity (split-screen view is ideal)
- Width and AP measurement

Color Doppler evaluation (longitudinal [sagittal] and/or transverse view) of both testes
- Parenchymal blood flow evaluation
- Measurement of varicocele size in mid-sagittal and/or mid-transverse view

Transducer selection. A high frequency (7.5-10 MHz) transducer should be used for scrotal scanning. Broad bandwidth transducers offer 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 a large tests and to compare the tests, the frequency is usually lower, resulting in a less detailed image. Color and spectral Doppler become 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 medially to lateral to get an overall impression of the tests 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 is 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-screen capabilities, comparative views of echogenicity and blood flow can easily be made and documented.

The use of CE 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
will be detailed in the section on indications (Part 2, July 2007).

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