Penile Evaluation: An Illustrated Review

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Abstract: High-frequency ultrasound is the imaging modality of choice for evaluating penile pathology because of its easy access, low cost, and patient tolerance (*The Penis, Diagnostic Ultrasound, second edtion*. Boca Raton: CRC Press; 2007:957–978). This pictorial review will illustrate the sonographic features of emergent and nonemergent penile conditions such as penile fracture, spongial tear, urethral injury, various types of priapism, erectile dysfunction, penile abscess, and Mondor disease.

Key Words: penile imaging, penile trauma, erectile dysfunction, penile emergencies.

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Ultrasound is the first-line imaging modality in the evaluation of penile pathology. Although uncommon, penile trauma and vascular emergencies require a prompt diagnosis to guide appropriate management and should be considered an emergency. Patients may seek an emergent evaluation with minor injuries, and diagnostic assessment must distinguish acute from nonacute pathologies.[1] This can be challenging because of the presence of overlapping sonographic features. This pictorial review will illustrate the ultrasound findings of various penile pathologies, including penile fracture, posttraumatic or postsurgical changes in the absence of fracture, and low- and high-flow priapism. Typical results of erectile dysfunction will also be reviewed.

PENILE ANATOMY

The penis comprises 3 muscles with 2 corpora cavernosa along the dorsal surface of the penis and one corpus spongiosum along the ventral surface.[2] On sonographic evaluation, a layer of connective tissue, known as the tunica albuginea, surrounds the corpora and appears as a thick hyperechoic line. The urethra runs through the corpus spongiosum (Fig. 1). The 2 corpora cavernosa are divided by a septum formed by the tunica albuginea. This septum is complete in the proximal one third of the penis and fenestrated in the distal two-thirds.

The blood supply to the penis typically originates from the internal pudendal artery, although it can arise from other pelvic vessels. Penile vasculature consists of the dorsal penile arteries, cavernosal arteries, and a bulbourethral artery. The Cavernosal artery travels through each corpora cavernosa, giving rise to multiple helicine arteries. The dorsal artery travels between the Bucks fascia and the tunica albuginea to supply the glans penis. The bulbourethral artery travels along the corpora spongiosum. The venous drainage of the penis consists of both deep and superficial dorsal veins.

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SONOGRAPHIC TECHNIQUE

The penis is best evaluated with high-frequency linear transducers (7.5–12 MHz).[2] The patient should be positioned supine with the penis along the anterior abdominal wall or set over a towel or sheet between the patient's thighs. The penis should be evaluated with grayscale and color flow Doppler in the transverse and sagittal planes from the base to the glans. Blood flow within the cavernosal arteries and deep dorsal veins should be documented with spectral Doppler.

PENILE TRAUMA

Penile Fracture

Penile fracture is a rare surgical emergency caused by a rupture of the tunica albuginea. It typically involves one corpus cavernosum and, less commonly, the corpus spongiosum or both cavernosa. Concurrent urethral injury occurs in 11% to 29% of cases and, in rare cases, can involve disruption of penile vasculature.[3] The most common etiology is penile trauma during sexual intercourse (60%), as the stretched tunica albuginea is thinned to 10% to 25% during the tumescent phase and thus more prone to injury.[4] Ultrasound is the preferred imaging modality for emergent evaluation due to its accessibility, low cost, and ability to delineate the extent of the fracture. On ultrasound examination, the hyperechoic tunica albuginea discontinuity can be identified with or without accompanying hematoma (Fig. 2). Ultrasound has a sensitivity of up to 88% and a specificity of up to 100% for identifying penile fractures.[5] Other imaging options include magnetic resonance imaging (MRI) or evaluation by cavernosography or retrograde urethrography for urethral injury.

Mimic of Penile Fracture

Post–Collagenase Treatment of Peyronie Disease

Targeted injection of collagenase is a treatment option for Peyronie disease. This collagenase dissolves plaque along the corpora. In the posttreatment setting, the tunica albuginea can become thin and almost imperceptible,[6] and there may be accompanying hemorrhage, mimicking penile fracture (Fig. 3).

Intracavernosal Hematoma Without Penile Fracture

Isolated intracavernosal hematoma is a rare entity that can present with clinical history and symptoms similar to penile fracture. Intracavernosal hematomas, in the absence of fracture,

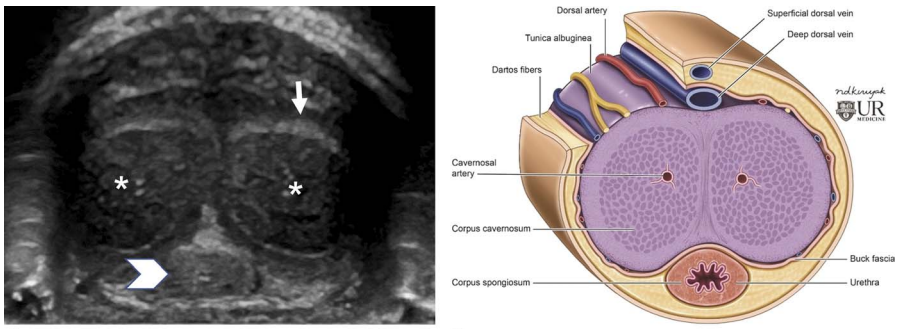


FIGURE 1. A, The penis consists of 2 corpora cavernosa (asterisk) and 1 corpus spongiosum (arrow head). The corpus cavernosum is surrounded by the tunica albuginea (arrow). B, Line drawing demonstrating detailed penile anatomy.

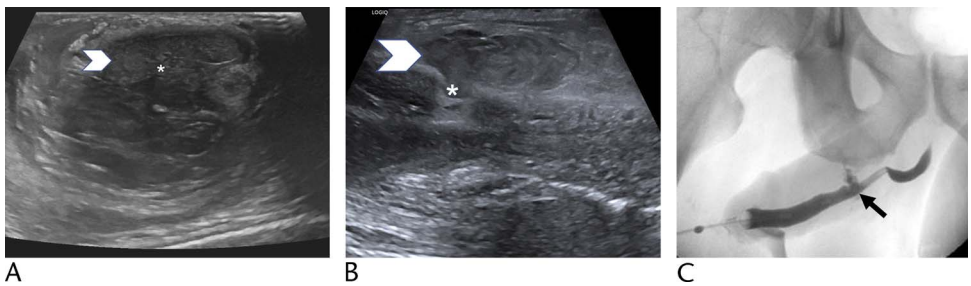


FIGURE 2. Fracture of the penis in a 24-year-old man. After sexual activity, the patient had loss of penile rigidity, pain, and hematuria. A, Transverse and (B) sagittal grayscale images of the penis demonstrate a defect in the right tunica albuginea (asterisk) with accompanying hematoma (arrow head). C, Retrograde urethrogram reveals associated rupture of the penile urethra (arrow). The patient subsequently underwent surgical exploration and repair.

are typically bilateral and may be caused by injury to the subtunical venous plexus or smooth muscle trabeculae.[7,8] They are usually caused by crush injury of the base of the penis against the pelvis, although cases of spontaneous hematomas in the absence of trauma have also been reported.[9] Physical examination findings may include the identification of a palpable mass.[10] Diagnosis and distinction from a penile fracture are based on ultrasound and MRI findings. Ultrasound evaluation demonstrates an intact tunica albuginea (Fig. 4). Hyperechoic foci raise suspicion for gas and urethral injury, which should be further evaluated with a retrograde urethrogram. Magnetic resonance imaging shows an intracavernosal mass with low signal intensity on T2-weighted images.[8] Unlike a penile fracture, treatment is conservative.

Corpora Spongiosal Hematoma

An isolated corporal hematoma of the corpora spongiosum is exceedingly rare, with few reported cases in the literature, and instead is often seen in conjunction with cavernosal injury.[11] Hematoma of the spongiosa can involve rupture of the tunica

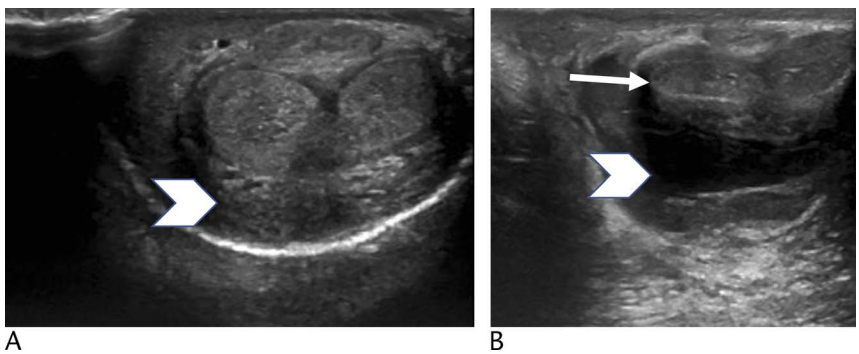


FIGURE 3. A 52-year-old man presents with painful erection after treatment with injection of collagenase. A, Transverse grayscale sonogram of the penis shows a heterogeneous collection (arrowhead) along the dorsal surface of the penis which represents a post procedural hematoma. B, Transverse gray scale sonogram of the base of the penis which shows a large homogenous hypoechoic collection along the dorsal surface of the penis (arrowhead). The tunica albuginea of the lateral left surface of the cavernosum is intact (arrow). Findings were consistent with a postprocedural hematoma.

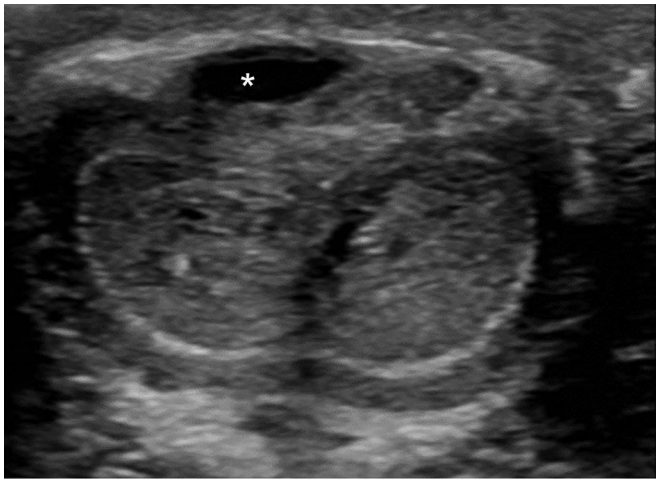


FIGURE 4. A 26-year-old man presents with penile pain during intercourse without loss of rigidity. A, Transverse grayscale image of the penis demonstrates a heterogeneous hypoechoic collection within the corpus spongiosum representing a penile hematoma (asterisk). The tunica albuginea is seen to be intact.

albuginea. However, this may not be sonographically evident as the tunica albuginea is discontinuous around the corpora spongiosum. Intraspongiosal hematoma, as elsewhere in the body, has varying appearances on ultrasound depending on the time frame in which it is imaged (Fig. 5). In the acute phase, a hematoma will appear hyperechoic as opposed to a chronic hematoma, which may appear heterogeneous and have liquefied components.[12]

Urethral Rupture

Sonography can evaluate the anterior urethra but is not well suited to assess the posterior urethra. Both direct and indirect signs of anterior urethral rupture can be detected by ultrasound. The most specific sonographic sign of anterior urethral rupture is a focal discontinuity of the urethral wall.[7] Tunica albuginea discontinuity, gas within the penile soft tissues, and corporal cavernosal hematomas have been associated with urethral rupture. It is important to note that urethral rupture is seen in 10% to 20% of cases of penile fracture (Fig. 2).[7]

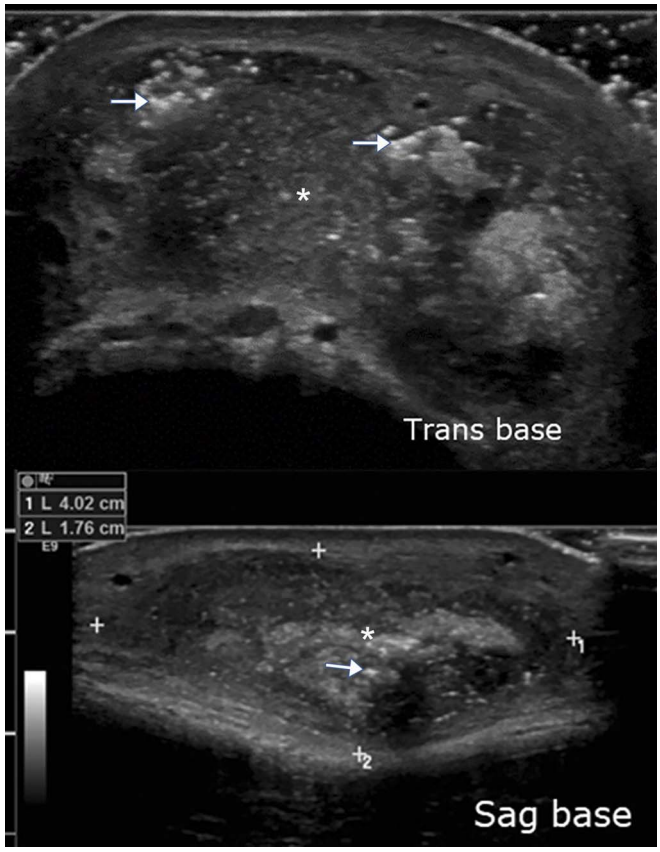


FIGURE 6. A 52-year-old man presents with a red, inflamed, and painful penis. A, Transverse grayscale image demonstrates a large collection (asterisk) within the corpora cavernosa with multiple echogenic foci (arrows) representing air. B, Sagittal grayscale image showing the same fluid collection, compatible with penile abscess.

Infections

Penile Abscess

Penile abscesses are most commonly seen in patients with underlying conditions such as diabetes, and these can be

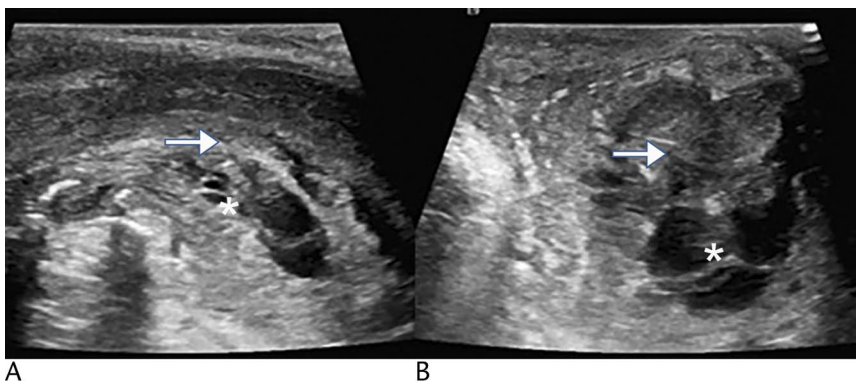


FIGURE 5. Cavernosal hematoma in a 44-year-old man presenting with pain after intercourse. A, Sagittal and (B) transverse grayscale images demonstrating a heterogeneous collection along the right cavernosum representing a hematoma (asterisk). The adjacent tunica albuginea is intact (arrow).

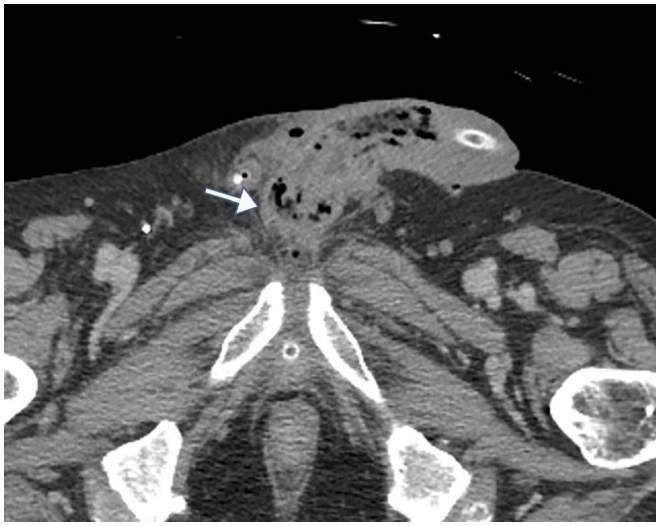


FIGURE 7. Penile prosthesis explant in a 72-year-old man. Axial contrast-enhanced CT of the pelvis at the level of the base of the penis demonstrates extensive air (arrow) within the penile parenchyma, mimicking penile abscess.

TABLE 1. Criterion Standard for Diagnosing Low-Flow Priapism Is Arterial Blood Gases

Blood Gas Findings of Priapism			
	P_{O_2}, mm Hg	P_{CO_2}, mm Hg	pH
Normal arterial blood	>90	<40	7.4
Normal mixed venous blood	40	50	7.35
Low-flow priapism	<30	>60	<7.25
High-flow priapism	>60	<40	>7.25

The blood gas values of low- and high-flow priapism are summarized in Table 1.[16]

identified with ultrasound, MRI, or computed tomography (CT).[13] The imaging appearance is similar to abscesses in any other body part. A well-defined fluid collection with a heterogeneous echotexture and surrounding hyperemia can be visualized on ultrasound (Fig. 6). Treatment includes drainage and antibiotics.

Penile Abscess Mimics

Penile Prosthesis Explant

A penile prosthesis is increasingly becoming more common as a treatment option for men with erectile dysfunction. Imaging an intact penile prosthesis presents challenges beyond this article's scope.[14] In the postexplant setting, it is important not to mistake subcutaneous and intracavernosal air for a penile abscess (Fig. 7).

Vascular Diseases

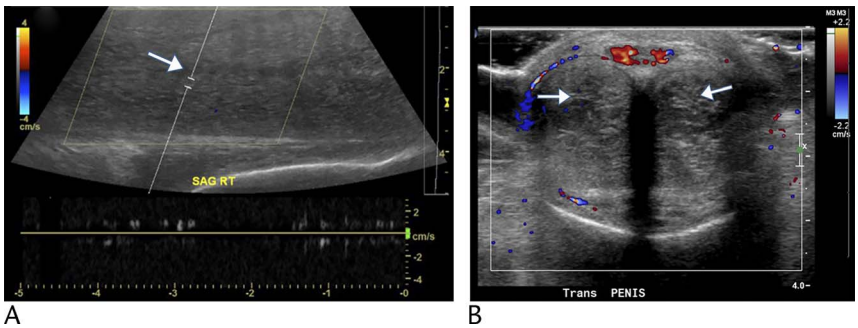
Low-Flow Priapism

Priapism is a prolonged erection unrelated to sexual intercourse or stimulation. There are 2 types of priapism: high- and low-flow priapism.[15] Low-flow priapism is a surgical emergency, and this painful condition results from ischemia to the penis secondary to a thrombus in the sinusoidal arteries or venous occlusion. Causes of low flow priapism include thrombotic disease, dyscrasias, pharmacologic, neurologic, and underlying malignancy. Color flow Doppler findings include the absence of flow or low-velocity flow in the cavernosal arteries. High resistance waveforms and potential reversed diastolic flow can be seen from outflow/venous occlusion. The criterion standard to diagnose low-flow priapism (ischemic priapism) is the level of oxygen present in the corporal blood (Table 1, Fig. 8).

Stuttering priapism, a rare variant of ischemic priapism, is a condition in which the patient experiences recurrent or intermittent episodes of painful erections that are usually under 4 hours. The exact pathophysiologic cause is unclear.

High-Flow Priapism

High-flow priapism is a rare pathology in which an arteriovenous fistula causes an increase in flow in the corpora. This increases the rigidity of the penis but is typically painless and does not require emergent intervention.[2,15] The most common causes of high-flow priapism are iatrogenic or traumatic. Imaging evaluation focuses on localizing the arteriovenous fistula by ultrasound or MRI. Sonographic findings include arterialized venous flow, increased diastolic arterial flow, and an increase in the size and amount of flow in a downstream vein (Table 1, Fig. 9).



A B

FIGURE 8. A 40-year-old man with cocaine-induced priapism. A, Transverse gray scale of the penis demonstrates engorged corpora cavernosa with no flow in the cavernosal arteries (arrow). The longitudinal view shows absences of flow in the cavernosal artery confirming hypoxic changes.

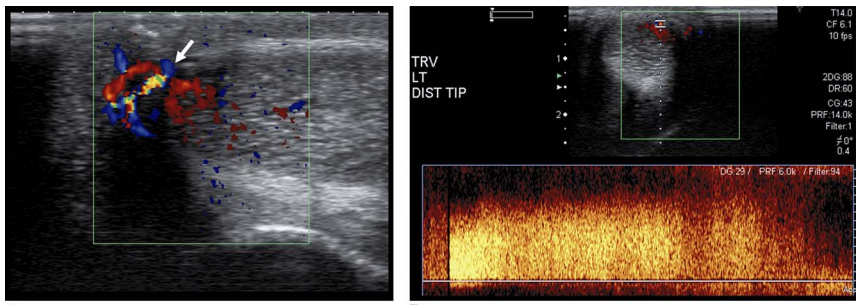


FIGURE 9. A 27-year-old man with painless persistent erection after recent penile injury from bull riding. The longitudinal color flow sonogram of the penis shows an area of color flow aliasing (*arrow*) within the left corpus cavernosum near the tip of the penis. B, Spectral waveform demonstrates a high-velocity, low-resistance blood flow pattern confirming the presence of a fistula. Images used with permission from the *Journal of Ultrasound in Medicine*.

Mondor Disease

Mondor disease is sclerosing thrombophlebitis of the deep vein of the penis.[17] The imaging and clinical presentation are similar to thrombophlebitis elsewhere in the body. The dorsal surface of the penis will be red and inflamed. On imaging, an occlusive thrombus is visualized in the dorsal vein (Fig. 10).

Erectile Dysfunction

Erectile dysfunction is a common condition, defined as the inability to attain or maintain penile erections of sufficient quality to allow satisfactory sexual activity. Approximately half of the men between ages 40 and 70 years experience erectile dysfunction, with physical or organic, psychologic, and pharmacologic etiologies.[18] The most common cause of erectile dysfunction is a vascular disease resulting in endothelial dysfunction; comorbidity with cardiovascular disease, diabetes mellitus, hyperlipidemia, and hypertension is frequent.[19] Duplex ultrasound can evaluate for vascular causes of erectile dysfunction and distinguish between arterial inflow and venous leakage.

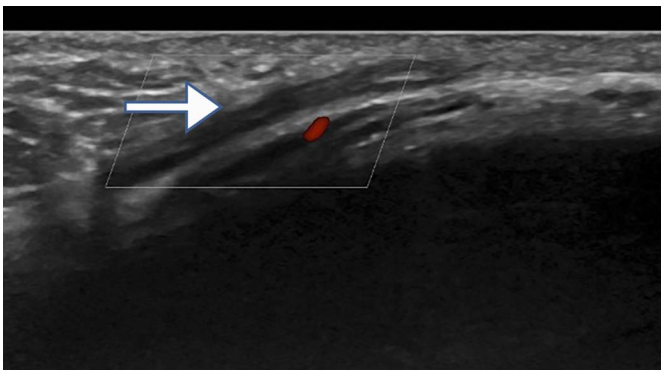


FIGURE 10. A 72-year-old man presents with Mondor disease of the penis. Sagittal color Doppler image hypoechoic clot and absent color flow in the deep dorsal vein (arrow) of the penis.

TABLE 2. Diagnostic Criteria of Erectile Dysfunction Caused by Venous Leakage and Arterial Inflow Disease

Imaging Characteristics of Erectile Dysfunction			
	Peak Systolic Velocity	**Resistive Indices**	**End-Diastolic Velocities**
Normal	>30	>0.80	<5 cm/s
Arterial inflow disease	<30	>0.80	<5 cm/s
Venous leakage	>30	<0.80	>5 cm/s

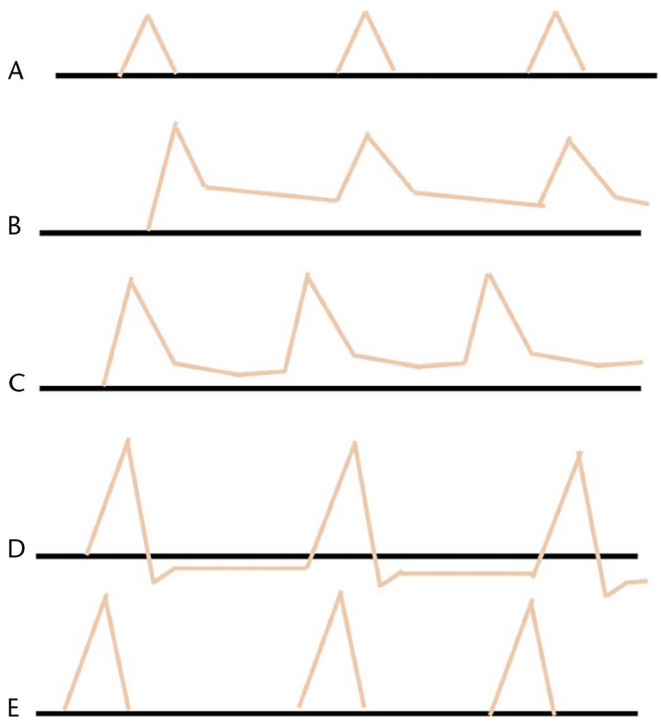


FIGURE 11. Line drawing demonstrating the expected cavernosal artery spectral Doppler waveforms before and after prostaglandin injection. A, Flaccid, before injection (monophasic waveform). B, Filling, 5 minutes after injection, increase in peak systolic velocity and end-diastolic velocity. C, Tumescence, 10 minutes after injection (decrease in end-diastolic velocity). D, Full erection 15 minutes after injection (with reversal of flow in diastole). E, Rigidity, 20 minutes after injection (decrease in peak systolic velocity).

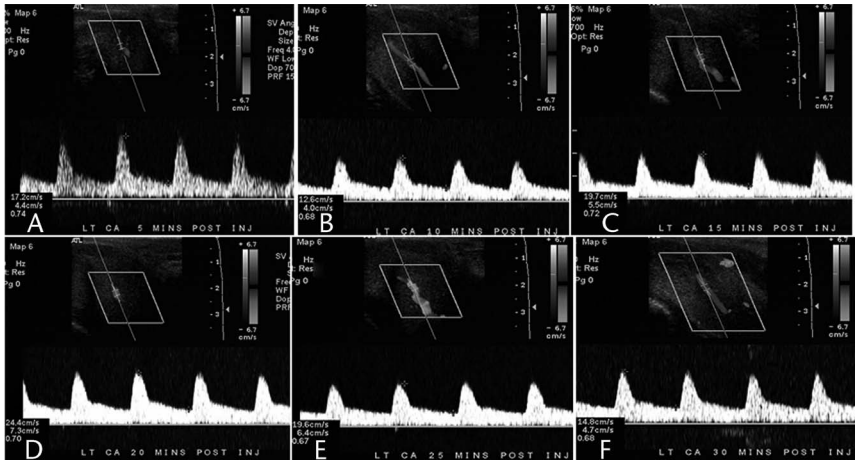


FIGURE 12. A 57-year-old man presents with erectile dysfunction. A–F, Sagittal spectral Doppler images from 5 to 30 minutes after prostaglandin injection show a maximum velocity within the cavernosal artery of 24 cm/s at 20 minutes, which is consistent with arterial inflow disease. In addition, an increased end-diastolic velocity greater than 5 cm/s is present, indicating accompanying venous leak.

Erection Physiology

The penile artery is a branch of the internal pudendal artery, and it trifurcates into the dorsal penile artery, cavernosal artery, and bulbourethral artery.[20,21] The excitement of the parasympathetic nervous system releases nitrous oxide, which results in vasodilation of the cavernosal penile arteries and their helical branches. Vasodilation of these vessels results in swelling of the corpus cavernosum and collapse of the penile veins. There are 2 prominent penile veins, both running along the dorsal aspect of the penis, the superficial dorsal vein and the deep dorsal vein. There are 4 stages of erection: flaccid state, filling phase, tumescent phase, and rigid phase (Table 2, Fig. 11).

Imaging Protocol

Our institutional protocol involves grayscale, color Doppler, and spectral Doppler assessment, as well as utilization of prostaglandin injection. First, grayscale transverse and sagittal images of the penis are obtained with a high-frequency linear probe. Next, peak systolic and end-diastolic velocities are recorded in the bilateral cavernosal arteries. Preinjection Doppler images of the dorsal vein are obtained. Ten micrograms of Prostaglandin E, an essential vasodilating agent, are injected in the distal two-thirds of the penile shaft in one corpus cavernosa using a tiny 30-gauge needle. Spectral Doppler waveforms are recorded in both cavernosal arteries starting 5 minutes after injection until 25 minutes elapse. Postinjection images of the dorsal vein are also obtained. Lastly, the patient is asked for a subjective estimate of the degree of tumescence and rigidity to conclude the study.

Patients should be screened for a history of priapism or conditions that may predispose them to priapism, as prostaglandin injection can precipitate these conditions.

Arterial Inflow Disease

Arterial inflow disease is an increasingly common cause of erectile dysfunction as the prevalence of peripheral arterial disease has increased.[20] The usual peak systolic velocity of a normal erection is greater than 30 cm/s; velocities between 25 and 30 cm/s are indeterminate, and peak systolic velocities less than 25 cm/s are diagnostic of erectile dysfunction (Table 2, Fig. 12).

Venous Leakage

Patients with venous leakage will have outflow through the deep dorsal vein during an erection.[21] Ultrasound can assess

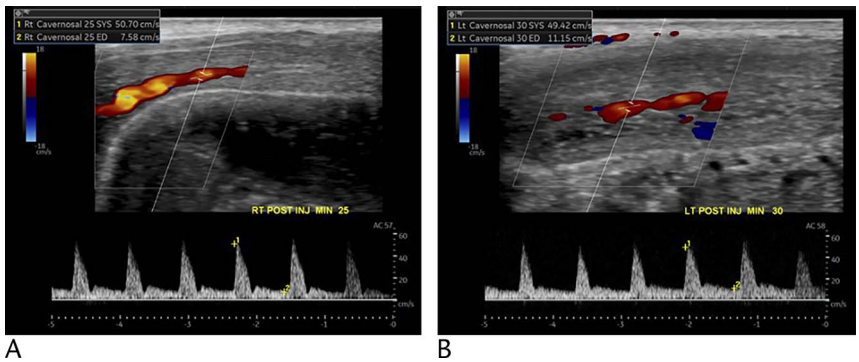


FIGURE 13. A 63-year-old man with erectile dysfunction. Sagittal spectral Doppler images from 25 (A) and 30 (B) minutes after prostaglandin injection showing an end-diastolic velocity within the corpus cavernosal artery of 7.6 and 11.5 cm/s, respectively, consistent with venous leakage.

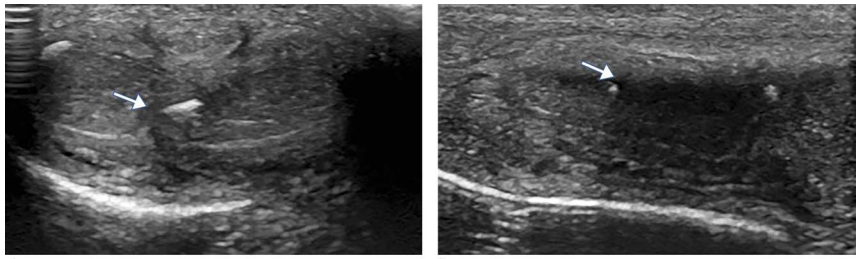


FIGURE 14. A 58-year-old man with Peyronie disease. Patient presents with a compliant of erectile dysfunction and an irregular curvature of the penis. A, Transverse grayscale sonogram demonstrating a calcified plaque (arrow) along the tunica albuginea. B, Sagittal gray scale sonogram of the same patient.

this directly by documenting flow within the dorsal vein or indirectly by observing a resistive index of less than 0.8 or an end-diastolic velocity greater than 5 cm/s (Table 2, Fig. 13).

Peyronie Disease

Peyronie disease is the most common cause of penile curvature.[21,22] This is most commonly evaluated on ultrasound, where it can be seen as calcified or noncalcified plaque along the tunica albuginea, most commonly on the dorsal aspect of the corpora (Fig. 14). The plaque can also be seen on MRI as thickening of the tunica or on CT, where calcified plaques can be visualized.

CONCLUSIONS

In summary, penile ultrasound has many applications. The portability and ease of rapid image acquisition and assessment make ultrasound the imaging modality for the initial evaluation of penile pathology. This pictorial review highlights some key sonographic findings that can direct surgical or nonsurgical management in the acute setting and the pertinent findings in characterizing nonemergent pathology such as erectile dysfunction.

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