Pictorial Essay

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Penile Emergencies–Demystifying the Sonographic Spectrum

음경 응급 상황–초음파 영상의 스펙트럼 이해

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Penile emergencies are uncommon and can be categorized as having infectious, vascular, traumatic, or multifactorial etiologies. To facilitate early diagnosis and treatment during emergency, US and color Doppler imaging are imperative. US depicts hypoechoic collections regardless of the presence of air foci in infections like abscess and Fournier's gangrene. Color Doppler imaging is conducted to evaluate vascular conditions such as penile Mondor disease (PMD) and priapism. PMD is indicated by the absence of color flow and non-compressibility of dorsal penile vein. Priapism can be categorized based on cavernosal artery flow: high flow and low flow. In traumatic injuries like penile fracture, US reveals breach in tunica albuginea with hematoma. Peyronie's disease can be multifactorial in origin and the imaging is commonly visualized as thickening of the tunica albuginea and echogenic calcified plaques. Urethral injuries are urethral discontinuity with adjacent collection. Urethral calculus is visualized as echogenic focus with posterior acoustic shadowing. Therefore, effective collaboration between radiologists and urologists is required for appropriate initial diagnosis and prompt treatment.

Index terms Penile Emergencies; Ultrasound; Abscess; Priapism; Thrombophlebitis; Peyronie's Disease

INTRODUCTION

Acute penile condition is broadly categorized as having traumatic, vascular, infectious, or multifactorial etiology and can be managed conservatively or surgically depending on the radiological imaging findings. US is the preferred imaging modality due to its wide availability, noninvasiveness, and high spatial resolution, which allow accurate visualization of penile anatomy. In addition, color Doppler US can be used for evaluation of vascular structures. Penile US during an emergency is usually performed using pharmaco-stimulants and has a satisfactory diagnostic yield. How-

ever, penile US post papaverine injection may improve detection of lesions in the tunica albuginea (TA) and intercavernosal septum (1). MRI can provide additional information for penile fractures and Peyronie's disease (PD). However, the limited availability of MRI and longer scan times can often lead to unnecessary delay in management (2). The aim of this pictorial essay was to review the US imaging spectrum of penile emergency. Figs. 1, 2 demonstrate normal US and color Doppler anatomy of the penis. Table 1 provides an overview of the various pathologies that affects the different anatomical parts of the penis using the key features seen on US imaging.

DISCUSSION

PENILE ABSCESS

Penile abscess is an uncommon urological condition presenting with a localized swelling and painful erection. Penile trauma and disseminated infection are major causative factors, along with intracavernosal injections of papaverine/silicone, and diagnostic cavernosography (3). In rare scenarios, priapism and penile prosthesis can be the causative factors (4, 5). Spon-

Fig. 1. Schematic and US Doppler normal penile anatomy.
A. Schematic diagram shows a normal penile anatomy (A: skin, B: superficial dorsal vein, C: deep dorsal vein, D: dartos fascia, E: Buck's fascia, F: tunica albuginea, G: urethra, H: CS, I: dorsal artery, J: CC, K: cavernosal artery, L: S).
B-D. Axial US (B) and color Doppler (C, D) images of the penile shaft post papaverine injection shows normal sonographic anatomy (CS, CC, S, tunica albuginea [yellow dotted arrow], Buck's fascia [yellow solid arrow], cavernosal arteries [orange arrows], dorsal arteries [red arrows], deep dorsal vein [blue arrows] and helicine arteries [green arrows]).
CC = corpus cavernosum, CS = corpus spongiosum, S = septum

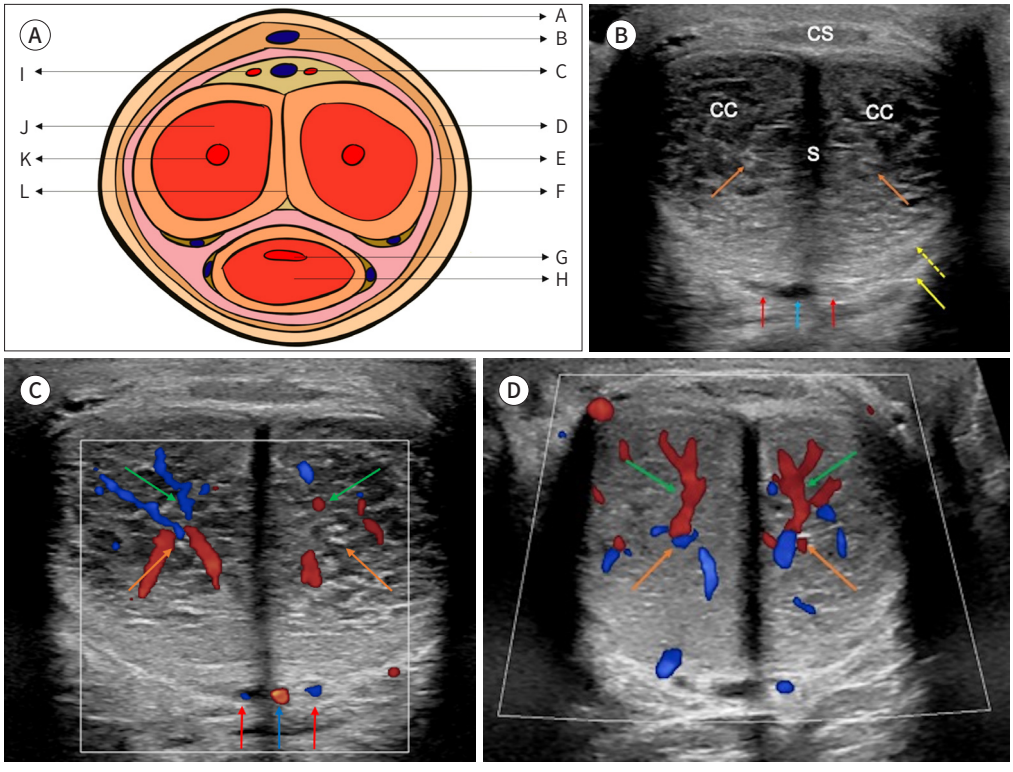


Fig. 2. Longitudinal US and Doppler sonographic penile anatomy.
A. Longitudinal US image shows a normal sonographic anatomy of the penis, post papaverine injection (CC, cavernosal artery [orange arrow], tunica albuginea [yellow dotted arrow], Buck's fascia [yellow solid arrow] and dorsal artery [asterisk]).
B, C. The corresponding longitudinal color Doppler US images shows color flow in the dorsal artery (B, red arrow) with normal peak systolic velocities and waveform (C) in the cavernosal artery (B, orange arrow).
CC = corpus cavernosum

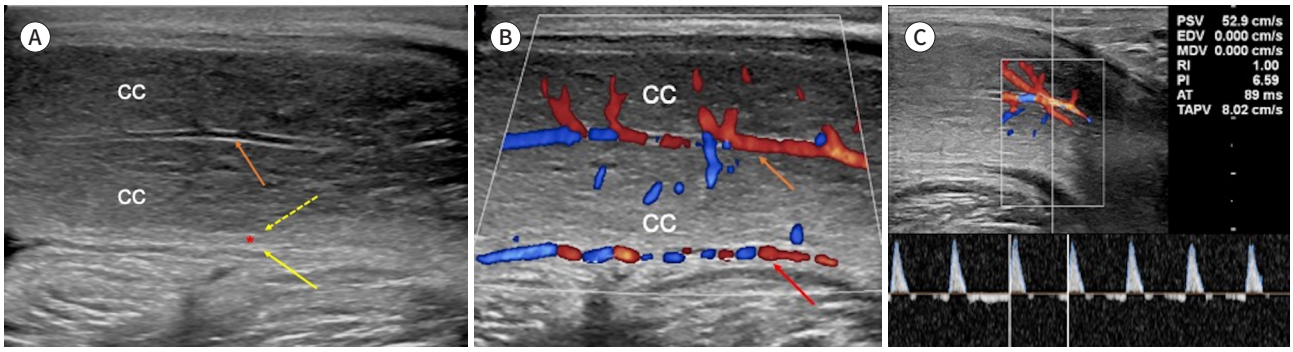
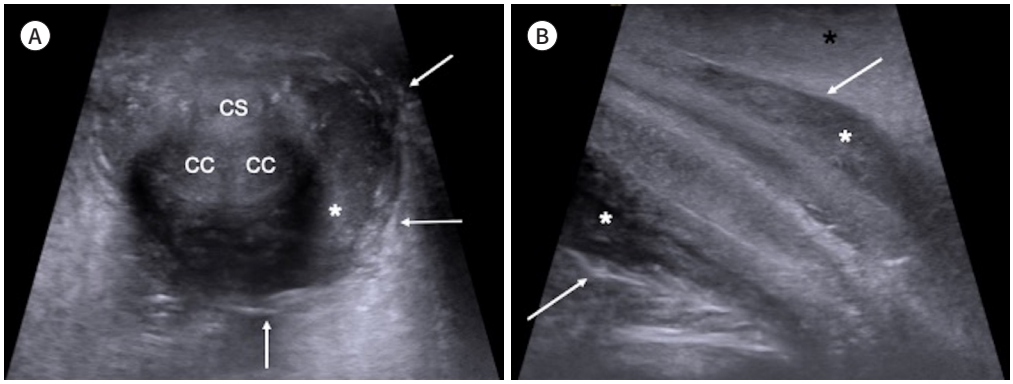


Table 1. Differential Diagnosis of Penile Emergencies

Anatomical Part	Diseases	Imaging Findings
Subcutaneous plane	Abscess	Hypoechoic collection with internal echoes
	Fournier's gangrene	Hypoechoic collection with subcutaneous edema and air foci
Dorsal penile vein	Superficial thrombophlebitis/penile Mondor's disease	Expanded, incompressible vein with echogenic contents and absent color flow
	Rupture of dorsal penile vein	Hematoma with non-visualisation of dorsal penile vein and intact tunica albuginea
Tunica albuginea	Peyronie's disease	Thickening/echogenic plaques with or without calcification
	Penile fracture	Discontinuity with hematoma
Corpora cavernosum	Abscess	Hypoechoic collection with internal echoes
	Peyronie's disease	Thickening/echogenic plaques with or without calcification
Intercavernosal septum	Peyronie's disease	Thickening/echogenic plaques with or without calcification
Cavernosal artery	Low flow priapism	Absent or trace high resistance flow with or without cavernosal infarction
	High flow priapism	
	Peyronie's disease	Elevated/normal cavernosal artery peak systolic velocities with high diastolic flow
	Arteriocavernosal fistula	Cavernosal artery encasement by echogenic plaques or cavernosal fibrosis
		Abnormal turbulent color flow with aliasing on color Doppler
Corpus spongiosum	Urethral injury with penile Hematoma	Hypoechoic collection with internal echoes in the peri-urethral region, with or without discontinuity
	Urethral calculus	Echogenic focus with posterior acoustic shadowing
Coronal sulcus	Sclerosing lymphangitis or benign transient lymphangiectasis of the penis	Irregular serpiginous palpable swelling involving the coronal sulcus. No definite role of imaging in diagnosis

taneous development of penile abscess without any identifiable cause have also been reported (6, 7). US reveals a subcutaneous or intracavernosal hypoechoic collection without flow on color Doppler imaging (Fig. 3). Assessment of the size, extent, and degree of liquefaction is imperative for feasibility of US-guided aspiration. Additionally, perineal/perianal regions and abdominal wall must be examined on US to isolate the foci of infection, which might second-

Fig. 3. A 29-year-old patient with penile abscess and complaints of fever and penile swelling.
A, B. Axial (A) and longitudinal (B) US images show a heterogeneously hypoechoic collection (white asterisks) beneath the tunica albuginea (white arrows) along the dorsolateral aspect of the penis, surrounding the CC and CS. Extensive overlying skin and subcutaneous edema are noted (black asterisk).
CC = corpus cavernosum, CS = corpus spongiosum



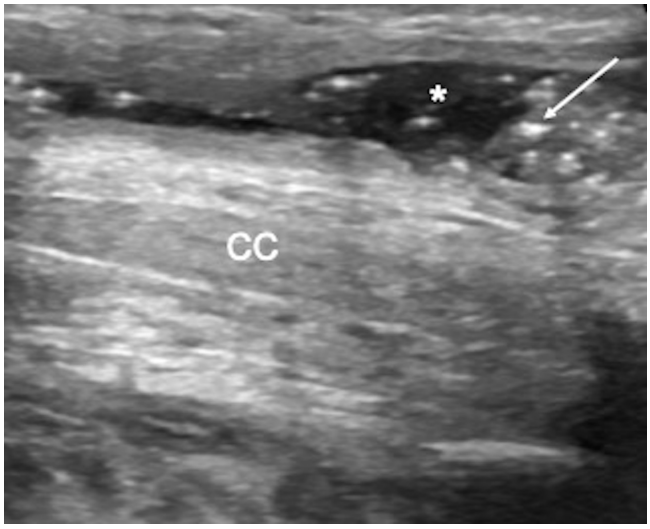


Fig. 4. A 48-year-old diabetes patient with Fournier's gangrene and complaints of fever, penile swelling, and discoloration in the perineal region. Longitudial US shows a heterogeneously hypoechoic collection (asterisk) with air foci (arrow), echogenic debris, and edema in the subcutaneous plane. Underlying CC appears normal.
CC = corpus cavernosum

arily extend to involve the penis via the Colles' or Buck's fascia (8, 9). Surgical drainage and intravenous antibiotics are the core treatment methods and reduce instances of abscess recurrence. However, it is recommended that minimally invasive US-guided aspiration be conducted because of the risk of erectile dysfunction (ED), penile deviation, fibrosis of the corpus cavernosum, and fistula formation with aggressive surgical intervention (10-12).

FOURNIER'S GANGRENE

Fournier's gangrene is a fulminant localized disease of the perineal region and scrotum, with occasional extension up to the penis and abdominal wall. It is characterized by genital pain and tenderness and has been associated with edema, blackish discoloration of the skin, subcutaneous crepitation, and purulent discharge from the wounds (13). Diagnosis is based on the history and clinical examination, with US showing subcutaneous edema and air foci, with or without an associated collection (Fig. 4).

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MONDOR'S DISEASE

Penile Mondor's disease (PMD) is a benign, self-limiting condition characterized by superficial thrombophlebitis of the dorsal vein of the penis. Patients with PMD present with a firm, thick, palpable cord-like swelling on the dorsal aspect of the penile shaft. The risk factors for PMD could be trauma/sexual intercourse, sexually transmitted diseases, surgery, dermatological conditions (Behcet's), thrombophilic states, or pelvic malignancy (14). Some case reports have described PMD as an unusual manifestation of systemic diseases such as metastasis from abdominal malignancy and sickle cell disease (15, 16). US imaging of PMD reveals intravenous thrombus seen as echogenic contents within an expanded incompressible vein and associated probe tenderness in the acute stage (Fig. 5). A color Doppler US confirms the absence of color flow within the distended vein (Fig. 5). Conservative management is the primary treatment of PMD with follow-up US to visualize the recanalization of the endoluminal thrombosis and resolution of the patients' symptoms (14). On rare occasions of severe persistent thrombosis, surgical treatment in the form of vein stripping can be considered (17).

PEYRONIE'S DISEASE

PD is a common condition that causes painful erection, deformity and shortening, resulting in ED. It has a multifactorial etiology and the predisposing factors are penile injury (sexual intercourse, trauma, surgical procedure or genitourinary instrumentation), diabetes mellitus, infection, and gout (18). PD has been associated with a positive family history (2% of cases); Dupuytren contracture an autosomal dominant inherited disorder primarily involving the palmar fascia; and Ledderhose disease, characterized by retraction of the plantar aponeurosis (19).

US reveals localized or diffuse thickening of the TA with echogenic plaques, which is often associated with calcification. An important aspect of imaging of PD includes the location, number, size, extent, and morphological characteristics of plaques. The plaques can be classified as tunical thickening (Fig. 6), calcification (Fig. 7), septal fibrosis (Fig. 8), or intracavernosal fibrosis (Fig. 9) according to the morphology and the location (1). Cavernosal artery encasement by plaques has also been implicated in arteriogenic ED.

PENILE FRACTURE

Penile fracture is a surgical emergency caused by blunt trauma to an erect penis with a

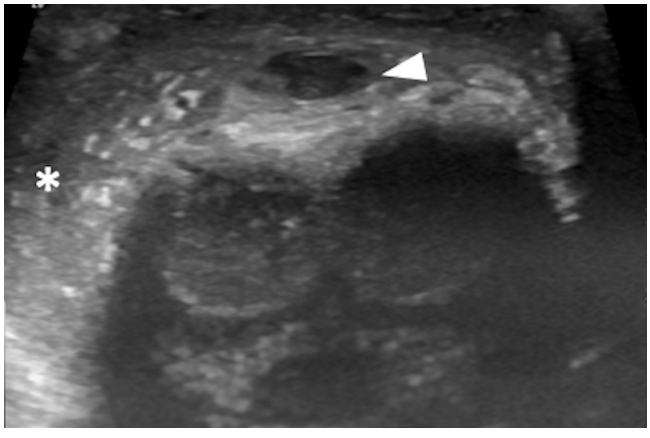


Fig. 5. A 32-year-old patient with Mondor's disease and history of pain and swelling post coitus axial US image shows an expanded superficial dorsal penile vein with echogenic contents (arrowhead) and associated subcutaneous edema (asterisk).

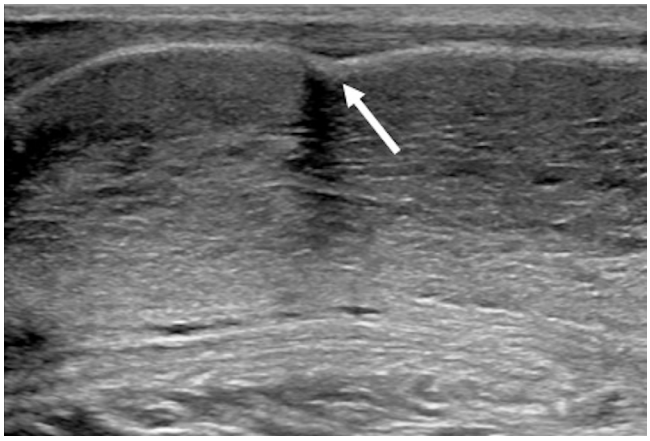


Fig. 6. A 50-year-old patient with Peyronie's disease and complaints of painful erections associated with penile curvature. Longitudial US shows focal thickening of the tunica albuginea (arrow). Posterior acoustic shadowing caused a deformity in the contour of the penile.

Fig. 7. A 56-year-old patient with Peyronie's disease and complaints of a palpable hardness on the penile shaft.
A, B. Axial (A) and longitudinal (B) US images demonstrate focal calcified plaques. Posterior acoustic shadowing involves the dorsal part of the septum and tunica albuginea (arrows).

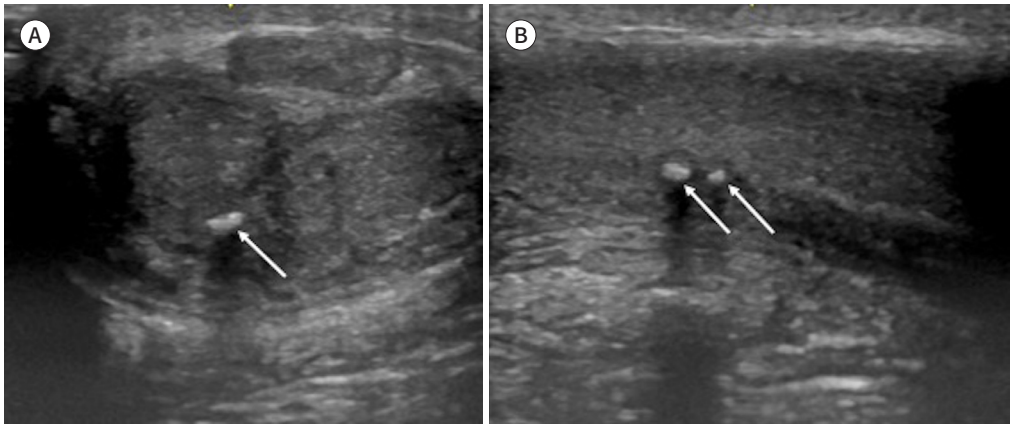
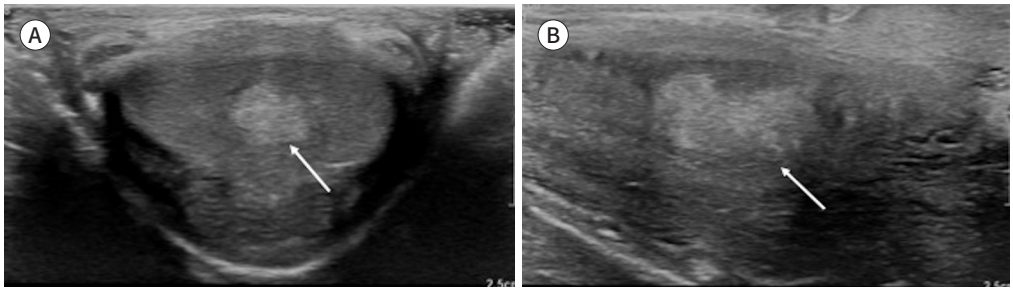


Fig. 8. A 39-year-old patient with Peyronie's disease and complaints of painful erection.
A, B. Axial (A) and longitudinal (B) US images show an irregular hyperechoic area involving the septum (arrows). The tunica albuginea appears normal.



typical history of a cracking sound followed by pain, swelling, ecchymosis ("Aubergine sign"), rapid detumescence, and penile deviation, often opposite to the site of injury. TA is the fibroelastic sheath that surrounds both corpora cavernosa and corpus spongiosum that reduces in thickness from 2–3 mm to 0.25–0.5 mm during erection, resulting in increased susceptibility to injury (20). US imaging not only localizes on the size and location of interruption or disrup-

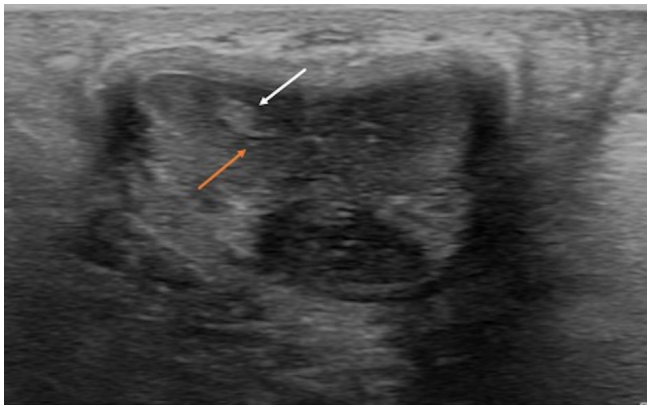


Fig. 9. A 46-year-old patient with Peyronie's disease and complaints of erectile dysfunction. Axial US shows a small focal hyperechoic area (white arrow) in the right corpus cavernosum, adjacent to the right cavernosal artery (orange arrow). The tunica albuginea and left corpus cavernosum appear normal.

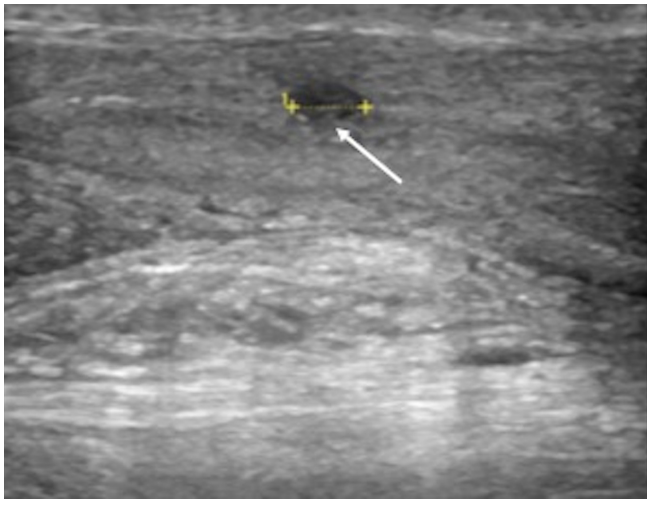


Fig. 10. A 39-year-old patient with penile fracture and complaints of swelling post sexual intercourse. Longitudinal US show a small ovoid hypoechoic hematoma (calipers) on the dorsal surface of the penis with an underlying defect (arrow) in the tunica albuginea.

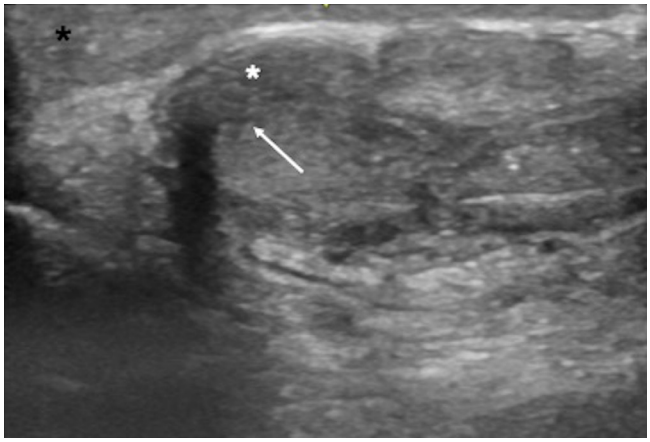


Fig. 11. A 34-year-old patient with penile fracture and history of cracking sound during sexual intercourse. Axial US show a heterogeneously hypoechoic hematoma (white asterisk) with a defect (arrow) on the ventral surface, involving the tunica albuginea of the right corpus cavernosum. Extensive overlying subcutaneous edema is seen (black asterisk).

tion of the TA but also identifies adjacent hematomas (Figs. 10-12). In cases of penile hematoma, a color Doppler US allows accurate and timely differentiation between a tear of the TA ("true" penile fracture) and vascular injury of the dorsal penile vein or artery ("false" penile fracture), which enables management of the condition. According to Metzler et al. (21), a tunical defect with intracavernosal hematoma as visualized on US imaging unequivocally indi-

Fig. 12. A 29-year-old patient with penile fracture and complaints of hematuria.
A, B. Axial (A) and longitudinal (B) US images show a heterogeneously hypoechoic hematoma (white asterisks) in the subcutaneous plane. A defect is seen in the tunica albuginea (arrows) with extensive overlying subcutaneous edema (yellow asterisk). The hematoma is close to the CS and possibly involves the urethra.
CS = corpus spongiosum

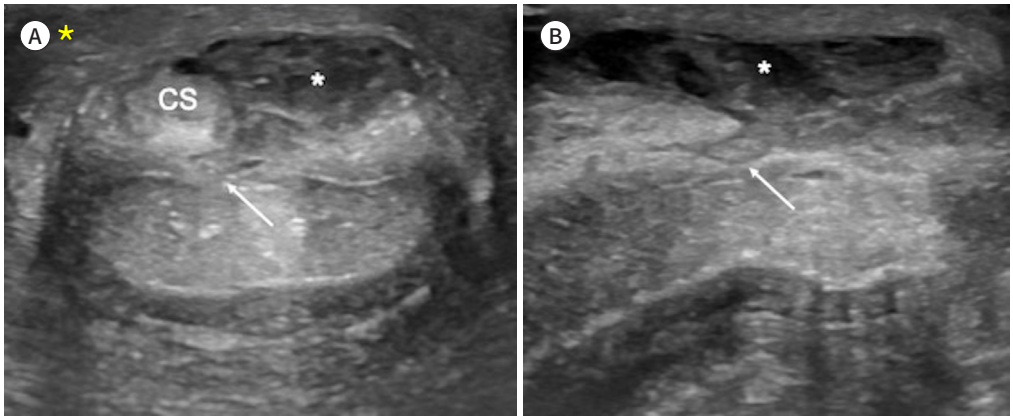


Table 2. Grades of Penile Fracture

Grade 0	Normal tunica albuginea, with or without rupture of dorsal artery/vein
Grade 1	Defect in tunica albuginea and/or cavernosal involvement
Grade 2	Defect in tunica albuginea and/or corpus cavernosum, with perialbugineal and/or cavernosal hematoma
Grade 3	Defect in the tunica albuginea, buck fascia and corpus spongiosum
Grade 4	Involvement of corpus spongiosum with urethral involvement and/or vascular malformation

Table 3. Types of Priapism with Imaging/Clinical Features

Ischemic (low flow) priapism	Absent or high resistance trace flow in the cavernosal artery
Non-ischemic (high flow) priapism	Elevated cavernosal artery peak systolic velocity with high end diastolic velocity
Malignant priapism	Primary tumor or penile metastasis
Stuttering priapism	Recurrent episodes of self-limiting painful erections lasting for a shorter duration, seen in patients with sickle cell disease

cates penile fracture, thereby guiding appropriate management. In addition, given that penile fracture is associated with the presence of concomitant urethral injury in 9%–20% cases, imaging for associated urethral and spongiosal injury is imperative (21, 22). Table 2 illustrates the grading of penile fractures as proposed by Shukla et al. (23). Long-term sequelae include painful erection, ED, penile plaques (causing deformity), urethral stenosis/fistula, and in rare scenarios a cavernosal artery fistula, which may lead to high flow priapism (24).

PRIAPISM

Priapism is defined as a prolonged erection lasting for more than 4 hours in the absence of sexual stimulation. Common causes of priapism include pro-thrombotic conditions, sickle cell anemia, pharmacological agents, recreational drugs, intracavernosal injection of pharmaco-stimulants, and neurological causes (e.g., spinal cord injury) (25-28).

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The most clinically relevant classification is either ischemic/low-flow or non-ischemic/high flow priapism. Rare subtypes of priapism include malignant priapism, priapism secondary to penile metastasis, and stuttering priapism, which is typically seen in sickle cell disease patients. It is characterized by recurrent episodes of self-limiting painful erections lasting for a shorter duration (<4 hours) (25, 29). Grayscale US imaging reveals engorged sinusoids, which are typically incompressible on applying probe pressure (30). Color Doppler imaging is the most useful modality for evaluation of cavernosal artery flow, which is often absent in ischemic priapism or may show traces of high resistance flow (Fig. 13). Prolonged absence of cavernosal artery flow with altered echogenicity of the corpora cavernosa indicates the possibility of cavernosal infarction. The dorsal artery often shows normal color flow, and low or absent flow in the dorsal vein owing to high intracavernosal pressure (Fig. 14). In contrast, non-ischemic priapism is characterized by normal or elevated cavernosal artery peak systolic velocities (PSVs) with high diastolic flow (Fig. 15). The sinusoids are engorged with blood, are often compressible, and do not show sinusoidal thrombosis. Prominent draining veins is an ancillary finding owing to the high venous outflow (31). Additionally, abnormal turbulent flow with aliasing on color Doppler US imaging could be indicative of an arterio-cavernosal fistula, which is a rare complication observed in post-traumatic cases (32). Table 3 shows the types of priapism and its salient imaging features. Ischemic priapism requires urgent aspiration of corporal blood to reduce intracavernosal pressure resulting in detumescence, thus preventing cavernosal thrombosis and subsequent fibrosis. Surgical shunting may be necessary if aspiration fails. High-flow priapism can require transcatheter embolization of the internal pudendal or cavernosal artery (30).

URETHRAL INJURIES

Injury to the penile urethra is most often due to iatrogenic trauma, with improper urethral catheterization accounting for up to 32% of all urethral injuries (33, 34). Prostatomegaly is the most common risk factor for these injuries owing to frequent visits to the emergency department for foley catheterization (34). According to the classification of urethral injuries, anterior urethral injuries involving the penile part may be associated with posterior urethral

Fig. 13. A 32-year-old patient with low flow priapism post oral intake of a pharmaco-stimulant (PDE-5 inhibitor).
A, B. Longitudinal color Doppler (A) and power Doppler (B) images show an expanded corpus cavernosum with no color flow in the cavernosal artery (arrows).

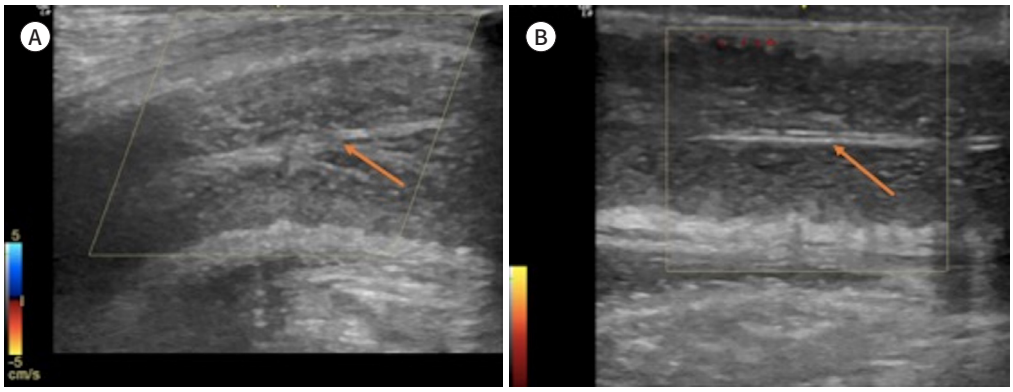
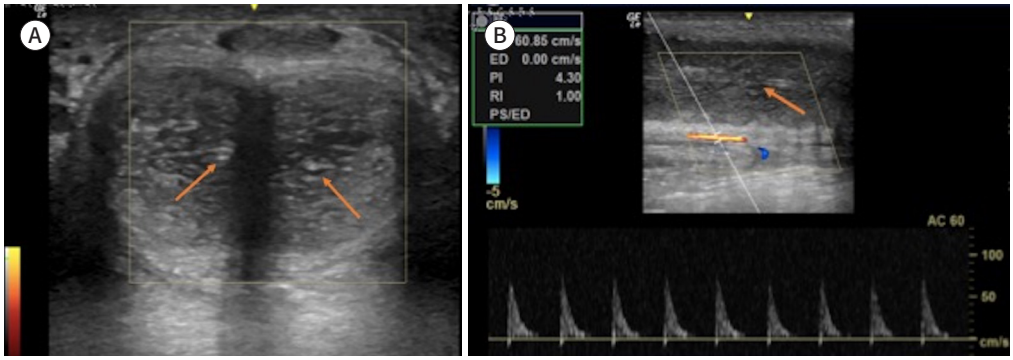


Fig. 14. A 43-year-old patient with low flow priapism.
A. Axial power Doppler image shows no detectable color flow in both cavernosal arteries (arrows).
B. Longitudinal color Doppler image demonstrates color flow in the dorsal artery of penis but none in the cavernosal artery (arrow).



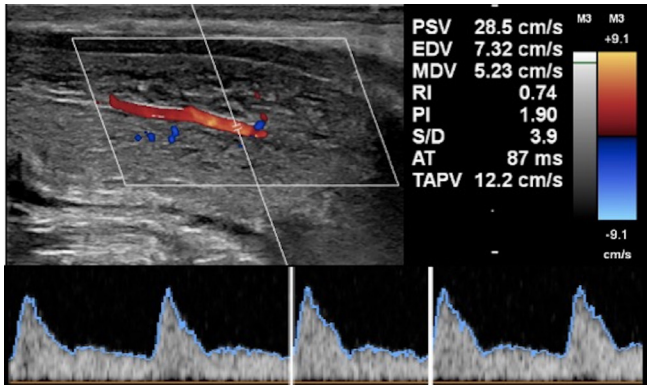
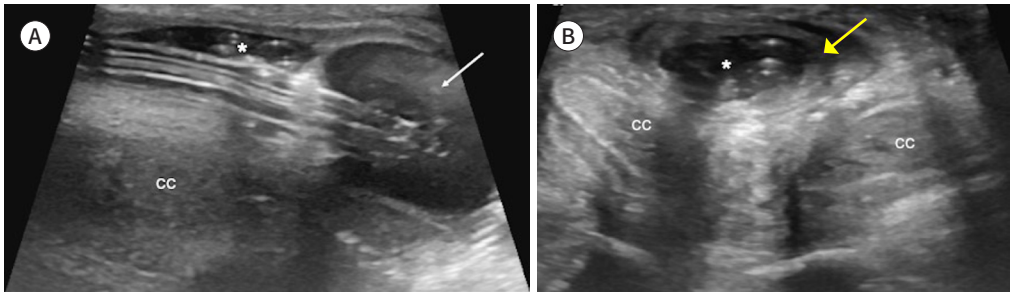


Fig. 15. Longitudinal color Doppler images of a 35-year-old patient with high flow priapism post injection of a pharmaco-stimulant shows an expanded corpus cavernosum with elevated peak systolic velocity and increased end diastolic velocity in the cavernosal artery.

Fig. 16. A 68-year-old psychiatric patient with benign prostatic hyperplasia and urethral hematoma after an attempted inappropriate self-extraction of Foley's catheter.
A, B. Transperineal longitudinal (A) and axial (B) US images show a heterogeneously hypoechoic collection within the corpus spongiosum (white asterisks) and in the periurethral region. The collection is seen traversing through a tear in the urethra (yellow arrow) into the perispongiosal region. A malpositioned inflated bulb of Foley's catheter is seen lying within the posterior urethra (white arrow).



injury (type 3) or may purely involve the anterior urethra (type 5) (35). US imaging can be used as the preliminary screening tool for anterior urethral injuries, which can occasionally reveal periurethral hematomas (Fig. 16). However, patients often undergo a retrograde urethrogram (RGU) for evaluation of the anterior urethra and may further require a CT scan for evaluation of concomitant posterior urethral and urinary bladder injuries such as in cases of

pelvic trauma (36).

URETHRAL CALCULUS

Urethral calculi are exceedingly rare, accounting for less than 2% of all urinary tract stones (37). These calculi are most commonly secondary calculi originating from the upper urinary tract or the urinary bladder but can rarely form in situ (38). Calculi impact is seen in the posterior urethra more frequently due to its non-distensible and narrow lumen, but up to 30% of all urethral stones are found in the anterior urethra (37, 39). US imaging may be used to confirm the presence of urethral calculi especially in patients with painful acute urinary retention and non-visualization of calculus in the urinary tract (40). US imaging shows a well-defined echogenic focus with posterior acoustic shadowing within the anterior urethra (corpus spongiosum) (Fig. 17). Undiagnosed impacted urethral stones can cause urethral injury, urinary retention, and rarely obstructive renal failure (38).

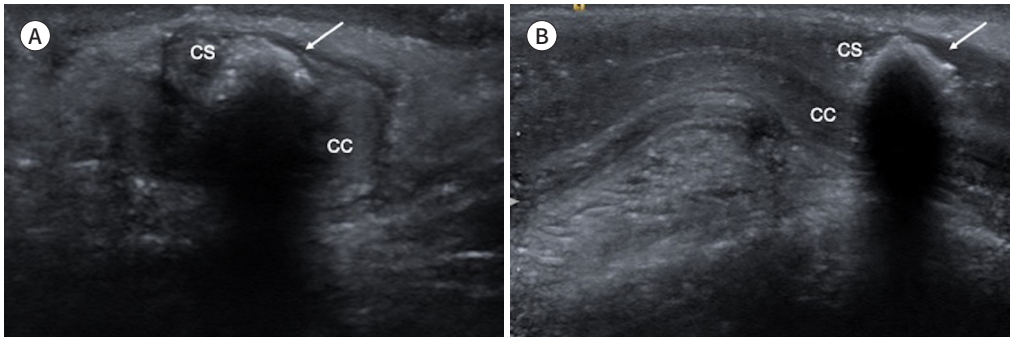
SCLEROSING LYMPHANGITIS

Sclerosing lymphangitis also known as benign transient lymphangiectasis of the penis (BTLP) is a spontaneously resolving self-limiting disease. Clinically, it is characterized by an irregular serpiginous palpable swelling typically involving the coronal sulcus or Balano-preputial furrow of the penis (41). The role of imaging remains indefinite for the diagnosis of this condition, but US and color Doppler imaging may be performed to rule out other penile lesions such as PD and PMD, respectively (42).

CONCLUSION

Penile emergency is uncommon and requires radiologists to be familiar with their specific imaging findings. US imaging is a noninvasive, cost - effective, readily accessible modality with a high resolution and plays a pivotal role in the identification of the abnormal imaging appearances of the penis. Prompt diagnosis of penile emergency is imperative to prevent long term complications and to avoid potentially irreversible sequelae.

Fig. 17. An 8-year-old patient with a urethral calculus and complaints of acute urinary retention and suprapubic pain.
A, B. Axial (A) and longitudinal (B) US images show a well-defined curvilinear echogenic focus (arrows) with posterior acoustic shadowing within the CS (anterior urethra).
CC = corpus cavernosum, CS = corpus spongiosum



Author Contributions

Conceptualization, S.A., M.A.; investigation, S.A., B.A.; methodology, B.A.; project administration, B.A., M.A.; supervision, B.A.; visualization, S.A.; writing—original draft, S.A.; and writing—review & editing, all authors.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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