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REVIEW ARTICLE

Role of color flow Doppler ultrasound in the evaluation of acute scrotal pain

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Abstract

Color flow Doppler ultrasound is a critical tool in the assessment of the scrotum. Ultrasound is the first-line imaging modality and can rapidly differentiate between surgical and nonsurgical conditions, allowing for appropriate and prompt patient management. We review the role of color flow Doppler in the evaluation of acute scrotal pain, highlighting some of the most commonly seen pathologies such as epididymo-orchitis and testicular torsion.

KEYWORDS
color flow Doppler, scrotal, torsion

1 | INTRODUCTION

Acute scrotal pain is a common presenting symptom for both pre- and post-pubertal males. High-frequency sonography remains the imaging modality of choice, with excellent sensitivity and specificity in diagnosing acute scrotal pathologies, such as epididymitis or testicular torsion.[1,2] Ultrasound is fast, portable, and allows for rapid evaluation of potential urologic emergencies. While grayscale imaging is helpful, color flow Doppler (CFD) ultrasound is the scrotal and testicular imaging's backbone.[3] This review will highlight the salient features in CFD evaluation of acute scrotum.

2 | NORMAL COLOR FLOW AND SPECTRAL DOPPLER

The paired testicular arteries serve as the vascular supply for the testes. These arise directly from the aorta and travel along the spermatic cord into the scrotum. Capsular branches course through the tunica vasculosa, just deep to the tunica albuginea, and give rise to centripetal arteries and recurrent rami, ultimately carrying blood away from the mediastinum and into the testicular parenchyma. One or more large transmediastinal arteries (Figure 1) can be seen in up to 50% of patients, supplying the capsular arteries and accompanied by the transmediastinal vein.[4] The superior vesicle artery gives rise to the deferential artery, which provides the ductus deferens and epididymis. In contrast, the inferior epigastric artery gives rise to the cremasteric artery, perfusing the scrotal sac and spermatic cord.[5]

Normal intratesticular spectral Doppler findings consist of high-flow, low-resistance waveforms (Figure 2). In healthy males, the mean resistive index is 0.62 with a range of 0.48-0.75.[6] This contrasts to the spectral tracings obtained in extratesticular tissues or cremasteric artery branch vessels, which demonstrate a characteristic high-resistance waveform pattern with a mean resistive index of 0.8.[7] The technique is of critical importance in CFD and spectral Doppler evaluation of the testes. Settings should be adjusted for slow flow, and in the acute stage, the asymptomatic side should be imaged first to optimize scanning parameters. The symptomatic side is then scanned, with no change in machine settings.

3 | INFECTION

3.1 | Epididymo-orchitis

Among the most common causes of acute scrotal pain in all age groups, epididymitis and epididymo-orchitis are readily identified by grayscale and CFD ultrasound. In sexually active men, sexually transmitted

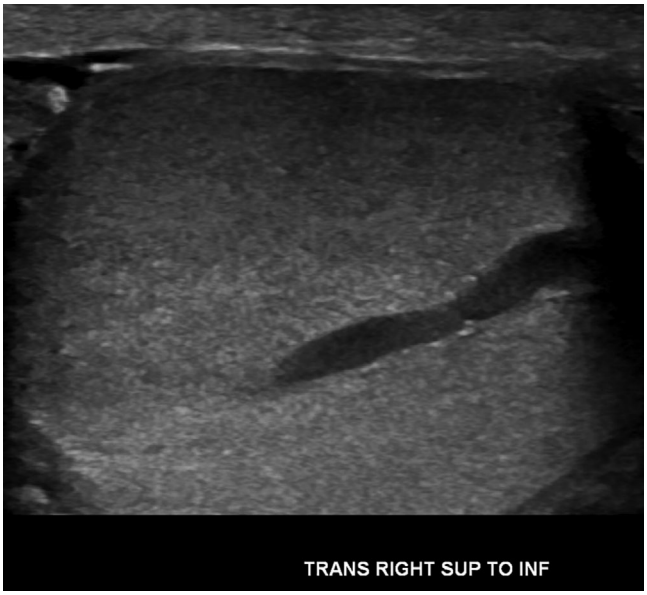


FIGURE 1 Grayscale transverse image of the right testis demonstrates a prominent transmediastinal artery, a normal finding in approximately 50% of patients

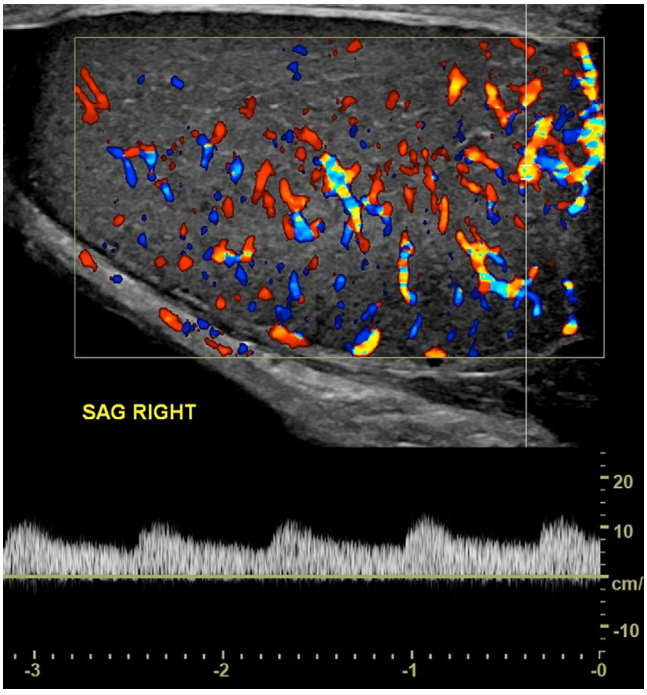


FIGURE 2 Normal intratesticular arterial waveform demonstrating a high-flow, low-resistance pattern

infection is a common etiology with causative organisms including *Chlamydia trachomatis* and *Neisseria gonorrhoeae*. In pre-pubertal boys and men who are not sexually active, ascending urinary tract infections can predispose to epididymitis, with causative organisms including *Escherichia coli* and *Proteus mirabilis*.[8] A positive Prehn's sign of decreased pain with the lifting of the symptomatic testis can indicate epididymitis over torsion in the setting of acute scrotal pain.[9]

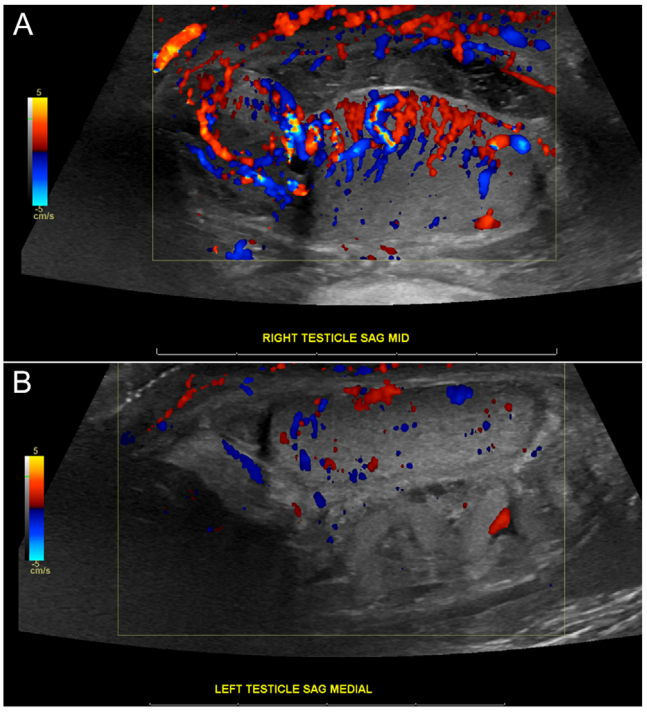


FIGURE 3 A 64-year-old male presents with acute right scrotal pain. (A) Color Doppler image of the right testis and epididymis demonstrates increased vascularity compatible with epididymo-orchitis. Note the complex pyocele anteriorly within the scrotal sac. (B) Normal vascularity in the left epididymis and testis

On grayscale ultrasound, the epididymis will appear enlarged and heterogeneous, and reactive hydrocele or pyocele may be present. However, these are secondary signs in the diagnosis of acute epididymitis. CFD will demonstrate *increased* blood flow on the painful side. Note that the mere presence of epididymal blood flow is not enough; rather the asymmetric increase compared to the asymptomatic side should be identified.[10] As such, comparison CFD views of the normal and painful sides helps make the diagnosis. Other non-infectious etiologies can result in epididymal hyperemia and heterogeneity, including trauma, sarcoidosis, tuberculosis, and brucellosis; these should be considered in the appropriate clinical context.[11,12]

In 20%–40% of cases, infection will directly spread to the testis, resulting in epididymo-orchitis (Figure 3). CFD images will demonstrate hyperemia of the affected testis in addition to the epididymis. Furthermore, spectral Doppler tracings will show increased flow and decreased resistance.[13] In healthy males, the resistive index is typically >0.5; however, in over half of patients with epididymo-orchitis, the resistive index was found to be <0.5.[14] Presumably, an acute inflammatory response may lead to decreased vascular resistance. Complications include venous infarction, with characteristic reversal of diastolic flow seen on spectral Doppler.[15]

Isolated orchitis can occur in the setting of mumps. In addition to testicular hyperemia, there may be the heterogeneity of the testicular parenchyma.[16] All patients should be followed to complete resolution,

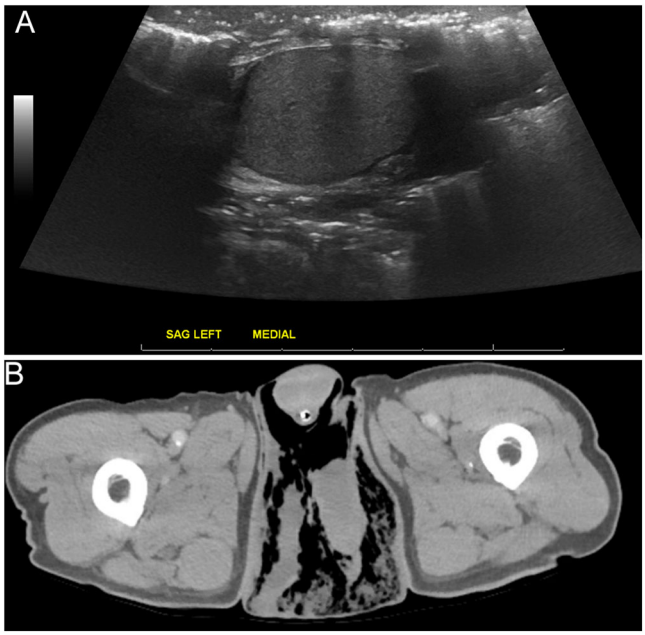


FIGURE 4 A 72-year-old male presents with fever, hypotension, and perineal crepitus. (A) Sagittal view of the left hemiscrotum demonstrates echogenic foci with reverberation artifact in the scrotal wall, compatible with gas. (B) Axial CT image shows extensive soft tissue emphysema in the scrotum and perineal region, compatible with Fournier gangrene

to exclude other parenchymal heterogeneity causes such as hematologic malignancy.

3.2 | Fournier gangrene

While more commonly diagnosed by computed tomography (CT), ultrasound can be used to diagnose the superficial infectious conditions of the scrotum. Fournier gangrene is a necrotizing soft tissue infection, resulting in air and inflammatory change within the paratesticular tissues. Sonographic findings will demonstrate gas within the scrotal wall (Figure 4) instead of gas secondary to bowel, which will be present in a non-parallel orientation away from the scrotal wall and within an inguinal hernia.[17] CFD will typically show preserved testicular and epididymal vascularity. Hyperemia of the soft tissues and scrotal wall can indicate infection.

4 | TORSION

4.1 | Complete testicular torsion

Most cases of testicular torsion are intravaginal. This frequently occurs in a bell clapper deformity setting, where the tunica vaginalis surround the scrotal contents. This prevents the testis from attaching to the scrotal wall and predisposes the spermatic cord to twist within the tunica vaginalis. The imaging findings of testicular torsion are primarily

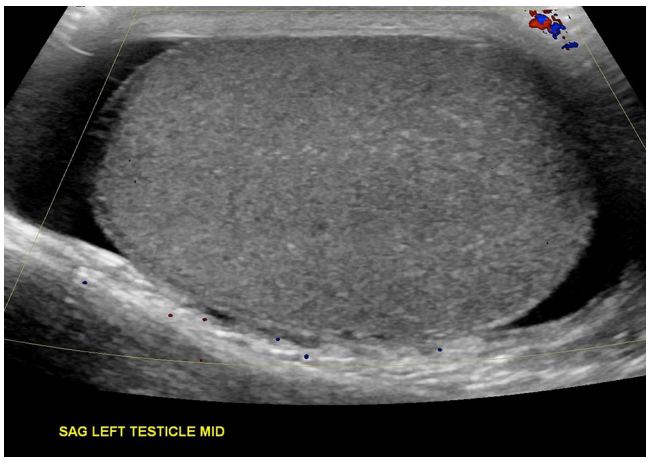


FIGURE 5 A 27-year-old male presents with acute left scrotal pain. Color flow Doppler image of the left testis demonstrates a complete absence of intratesticular blood flow, compatible with complete testicular torsion

determined by the degree to which the spermatic cord is twisted. Blood flow is variably present as the cord can twist anywhere from 180° to two full turns. Arterial disruption typically follows venous and lymphatic obstruction, with grayscale ultrasound demonstrating an enlarged, edematous testis.[18] CFD remains highly sensitive and specific in the evaluation of complete testicular torsion.[19] Grayscale findings may be normal in the early stages of ischemia, while optimized CFD images showing a lack of arterial blood flow to the affected testis may be the only indication of torsion (Figure 5). Venous flow should not be elicited. When present, venous flow is either normal or an indicator of epididymo-orchitis. The absence of venous flow should not be used in the interpretation of testicular torsion.

Special consideration should be given to identifying the torsion knot or whirlpool sign (Figure 6), a direct indicator of a twisted spermatic cord.[20,21] Although the epididymis is most commonly avascular given its blood supply from the testicular artery, the presence or absence of epididymal flow does not confirm nor exclude the diagnosis of testicular torsion. Similarly, the presence of high-resistance minimal artery flow at the periphery of the testis is not an indicator of testicular perfusion. It should not be used to exclude testicular torsion.

Certain conditions can predispose to the development of testicular torsion, including cryptorchism. The incomplete descent of the testis into the scrotum generally results in an asymmetrically small and hypoechoic testis. Ultrasound can help identify non-palpable testes within the inguinal canal, noting that a higher retroperitoneal testis may be challenging to visualize sonographically.

4.2 | Partial testicular torsion

Partial or incomplete testicular torsion is defined as the presence of abnormal intratesticular arterial flow. In patients with partial or incomplete testicular torsion, varying degrees of spermatic cord twist may be seen. This diagnosis may be made by combining the CFD and

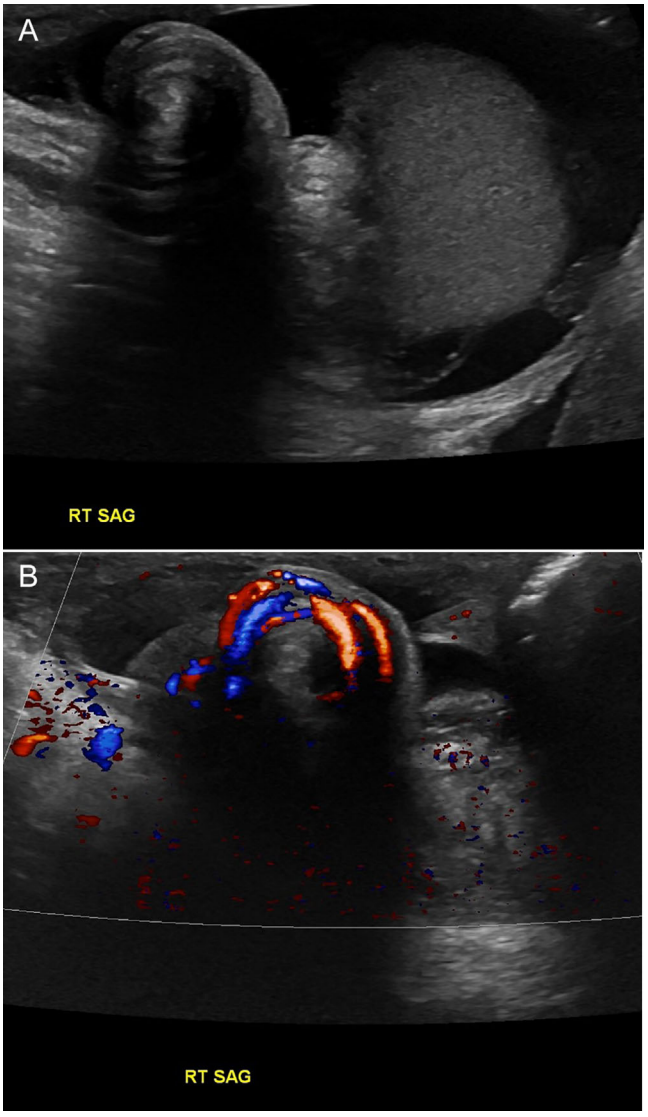


FIGURE 6 A 42-year-old male presents with acute right scrotal pain. Grayscale (A) and color flow Doppler (B) ultrasound images demonstrate the whirlpool sign, compatible with twisting of the spermatic cord. Testicular torsion was confirmed intraoperatively

spectral Doppler findings compared to the asymptomatic side. Various characteristic spectral Doppler waveforms seen in partial testicular torsion include monophasic waveform, reversal of diastolic flow, tardus parvus morphology, and spectral Doppler waveform variations within the same testis.

Increasing arterial resistance can lead to monophasic waveforms with diminished or absent forward diastolic flow (Figure 7).[22] Continued increased vascular resistance can lead to a frank reversal of diastolic flow, with spectral flow noted below the baseline. This pattern suggests impending testicular infarction.[23] Tardus parvus morphology of the intratesticular vasculature also indicates ischemia (Figure 8). The delayed systolic acceleration time and dampened amplitude are similar to tardus parvus waveforms elsewhere in the body, representing inflow abnormalities. Finally, when the spectral waveform varies within the same testis, this is worrisome for underlying ischemia (Figure 9).

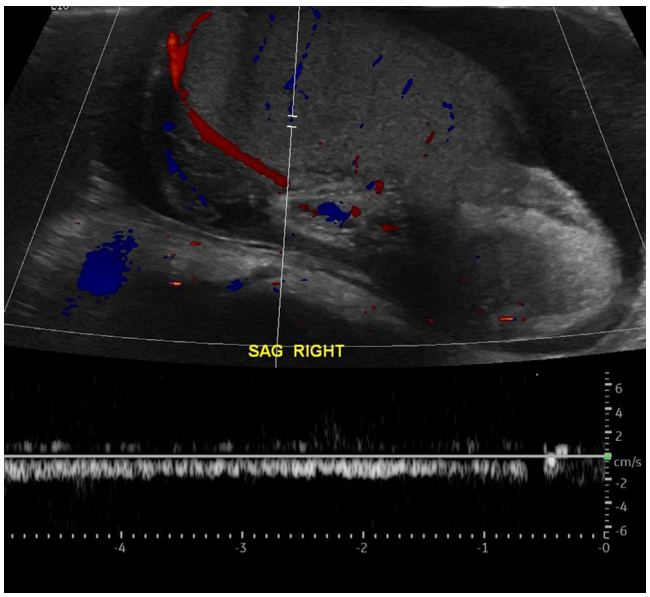


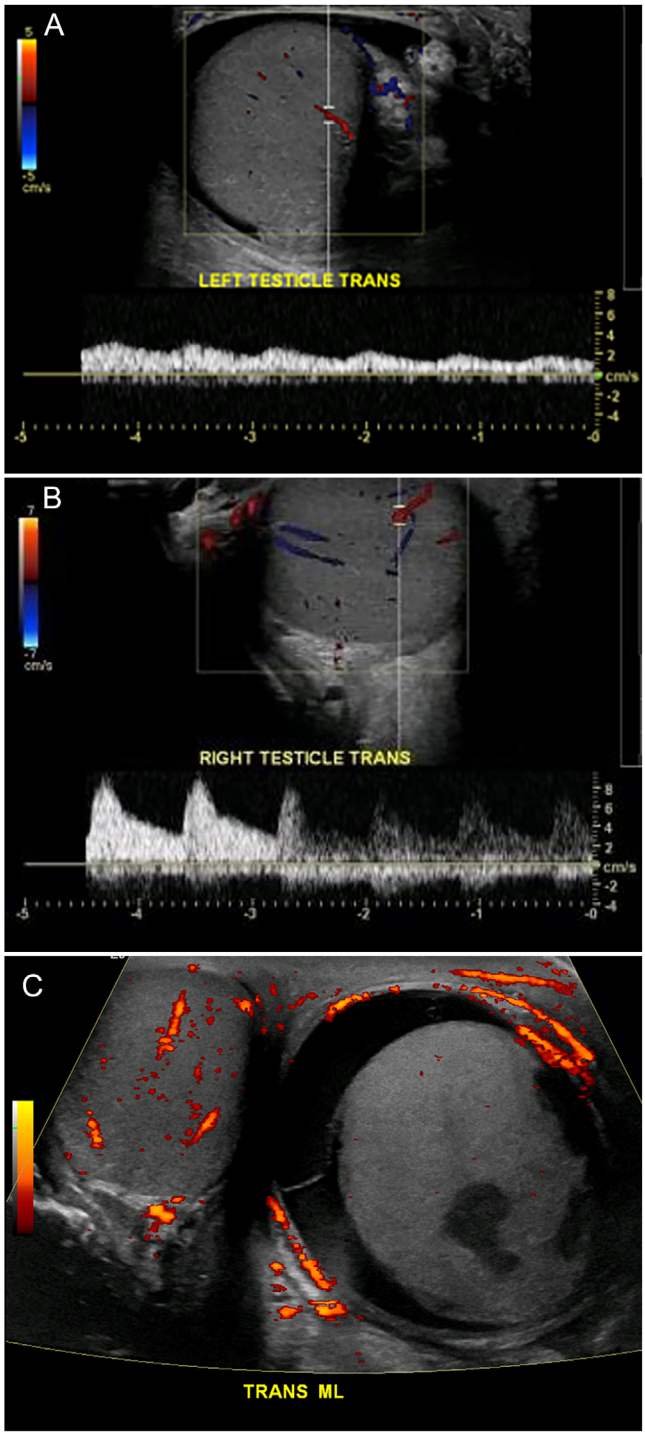
FIGURE 7 Spectral Doppler image of the right testis demonstrates an abnormal, monophasic waveform. Findings are compatible with partial testicular torsion, confirmed at surgery. Note that the presence of intratesticular flow does not exclude torsion

4.3 | Torsion–detorsion

Intermittent testicular torsion, or torsion–detorsion, requires appropriate clinical context. The definitive history of recurrent acute scrotal pain, with intermittent relief periods, is essential in making the diagnosis. When torsed, the testis lacks internal vascularity, as noted previously. However, once the testis detorses, there is reactive hyperemia (Figure 10).[24] This can sometimes be demonstrated within the course of a single ultrasound examination. The affected testis shows little or no internal vascularity at the start of the exam, while the increased flow is noted by the end. Most importantly, the patient will indicate an improvement or resolution in symptomatology to the sonographer or radiologist. Patients may ultimately present with multifocal testicular infarcts, as the diagnosis may be overlooked, or patients may delay medical care due to the waxing and waning nature of the underlying pain.

4.4 | Testicular ischemia

Note that an absence of Doppler signal within the testis is most commonly due to the spermatic cord's twisting. However, there are other potential etiologies for testicular ischemia, including vasculitis, drug-mediated vasoconstriction, inguinal hernia or following inguinal hernia repair, and severe infection that is not responding to antibiotic therapy.[25,26] In these settings, the clinical history is of utmost importance.



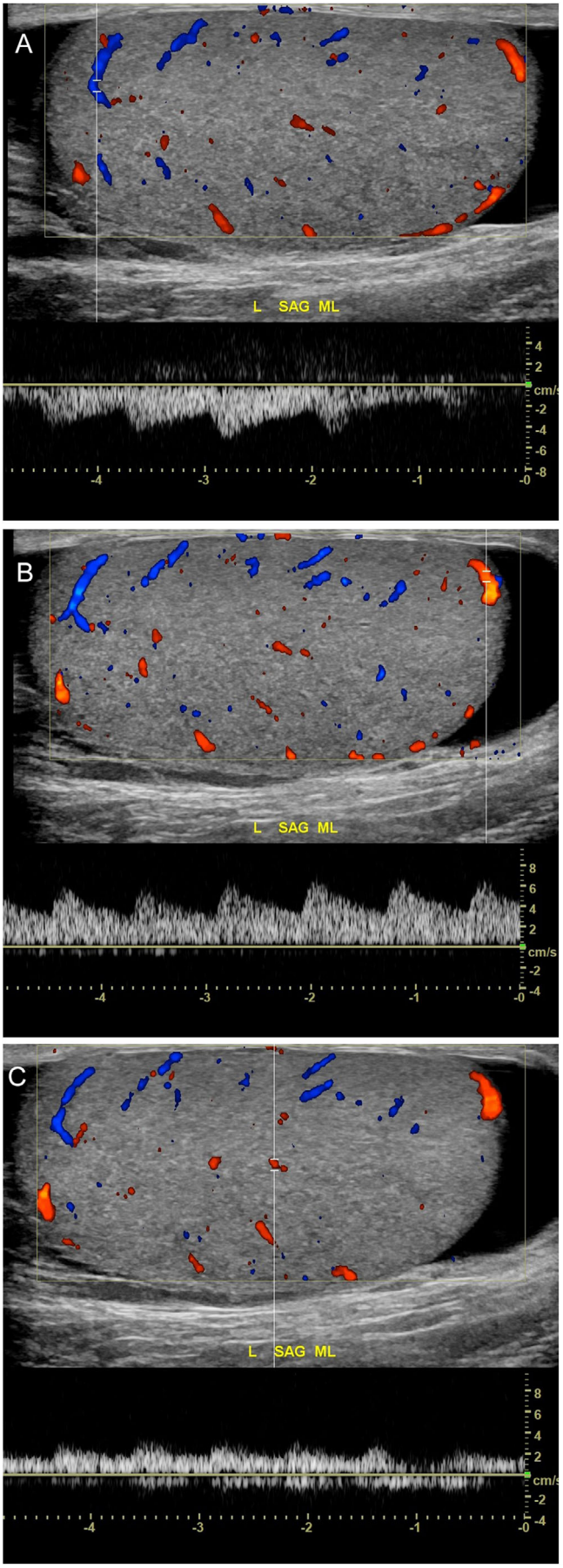


FIGURE 8 A 19-year-old male presents with acute left scrotal pain. (A) Spectral Doppler image of the left testis demonstrates an abnormal tardus parvus waveform morphology. (B) Spectral Doppler image of the contralateral right testis is normal. Unfortunately, diagnosis of partial torsion was missed. (C) Patient returned 11 days later. Color flow Doppler image of the left testis demonstrates no intratesticular perfusion and peripheral hypoechoic regions compatible with infarcts

5 | TRAUMA

Testicular trauma is a common indication for ultrasound, with findings ranging from small hematoceles to testicular rupture. CFD is essential in evaluating testicular perfusion, which may be at risk depending on the testis' degree of injury. Any findings suggestive of testicular rupture also raise concern for testicular ischemia. An injury to the tunica albuginea indicates an injury to the underlying tunica vasculosa, therefore, a disruption of the capsular artery.[27] A careful grayscale evaluation of the testicular contour is necessary to search for any deformities or parenchymal extrusion that would indicate rupture (Figure 11). Accompanying decreased vascular perfusion may be focal or global.

FIGURE 9 Spectral Doppler images of the left testis demonstrate normal arterial waveform in the upper (A) and lower (B) poles, with decreased arterial amplitude and abnormal morphology in the midpole of the same testis (C). Whirlpool sign (not shown) was also present. Patient was found to have partial torsion at surgery

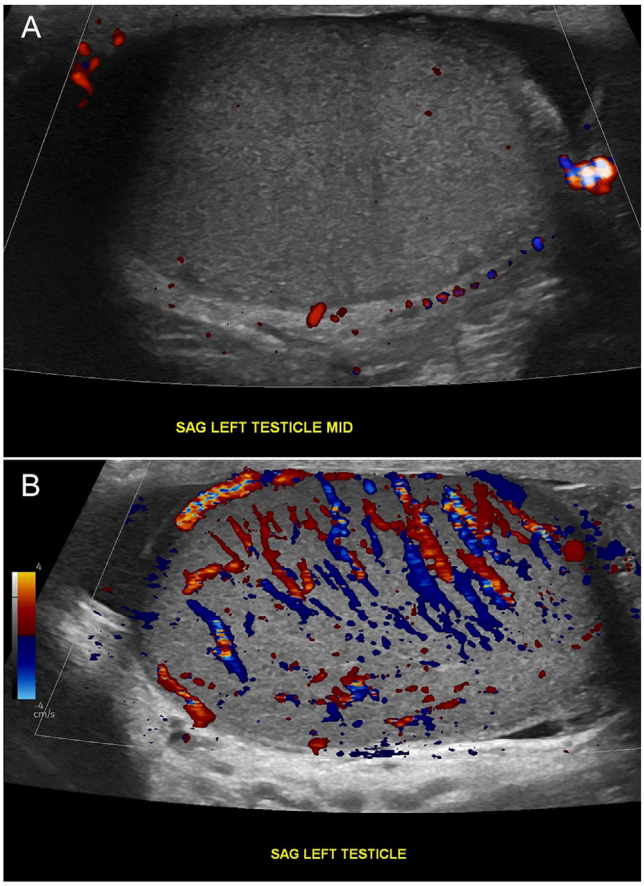


FIGURE 10 A 61-year-old male presents with acute left scrotal pain. (A) Color flow Doppler image of the left testis early in the exam demonstrates an absence of intratesticular flow, suggesting torsion. (B) Color flow Doppler image of the left testis 20 min into the exam demonstrates relative hyperemia. Patient reports improvement in his symptoms. Findings are compatible with torsion–detorsion

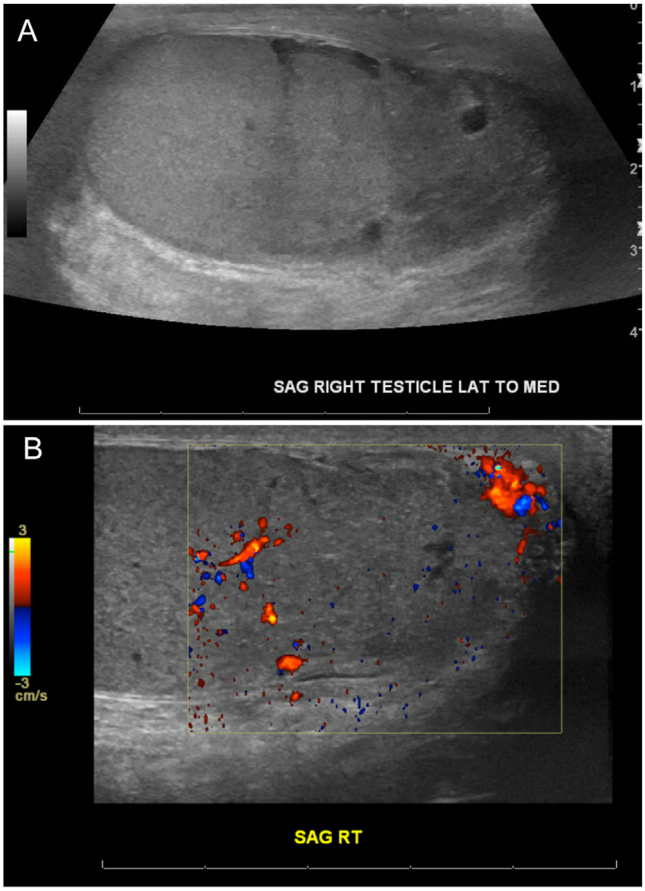


FIGURE 11 A 30-year-old male presents with motorcycle collision and blunt scrotal trauma. (A) Grayscale image of the right testis demonstrates a focal contour abnormality and disruption of the tunica albuginea at the lower pole. (B) Color flow Doppler image of the right lower pole demonstrates absent parenchymal vascularity at the site of disruption. Findings compatible with testicular rupture, with associated focal ischemia

6 | MALIGNANCY

CFD ultrasound is critical to help differentiate benign and malignant focal lesions. For example, even in trauma settings, 10%–15% of patients may have underlying malignancy, and CFD will help separate focal hematomas from focal neoplasm.[3] Similarly, 10% of patients with testicular tumors may present with acute symptoms such as pain.[28] Most testicular malignancies will demonstrate increased vascularity, noting that small lesions may be difficult to characterize by CFD adequately.

7 | VARICOCOELE

CFD can be used to diagnose subclinical scrotal varicocoeles. This has been covered in detail in this issue as an independent topic. Note that varicocoeles can be present as an isolated finding and represent

intra-abdominal pathologies, such as retroperitoneal malignancy or gonadal vein thrombosis.

8 | ULTRASOUND CONTRAST

Contrast-enhanced ultrasonography has emerged as an adjunct to CFD and spectral Doppler ultrasound. The use of contrast can help identify vascular or non-vascular etiologies in the setting of acute scrotal pain. In particular, the absence of contrast enhancement can help differentiate hematomas from scrotal neoplasm, identify complications such as infarcts, and aid in the diagnosis of testicular torsion.[29–31]

9 | CONCLUSION

Ultrasound is the first-line imaging modality used in evaluation for scrotal pathology. CFD is a critical diagnostic tool that can help differentiate acute scrotal pathologies, including epididymitis, complete testicular torsion, and partial testicular torsion. Understanding the normal and abnormal spectral waveform appearance of the intratesticular vasculature is invaluable. Note that given the challenges in identifying appropriate color and spectral Doppler changes in the setting of torsion, as well as cases of false-negative color Doppler ultrasound, surgical exploration is still recommended when there is strong clinical suspicion for testicular torsion.[32]

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest. Vikram Dogra is a guest editor of the special issue for which this manuscript is being submitted.

AUTHOR CONTRIBUTIONS

Akshya Gupta and Vikram Dogra both contributed to the acquisition and analysis of imaging information, drafting and revising the manuscript, as well as approving and submitting the manuscript.

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