

Acute Onset of Scrotal Pain-Without Trauma, Without Antecedent Mass

Variant: 1 Adult or child. Acute onset of scrotal pain. Without trauma, without antecedent mass. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler scrotum	Usually Appropriate	O
US scrotum	Usually Appropriate	O
MRI pelvis (scrotum) without and with IV contrast	Usually Not Appropriate	O
MRI pelvis (scrotum) without IV contrast	Usually Not Appropriate	O
CT pelvis with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT pelvis without IV contrast	Usually Not Appropriate	⊕⊕⊕⊕
Nuclear medicine scan scrotum	Usually Not Appropriate	⊕⊕⊕⊕
CT pelvis without and with IV contrast	Usually Not Appropriate	⊕⊕⊕⊕⊕

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Summary of Literature Review

Introduction/Background

The acute scrotum is a medical emergency defined as scrotal pain, swelling and redness of acute onset, from minutes to 1 to 2 days [1] and comprises at least 0.5% of all emergency department visits [2]. Etiologies of acute scrotum are numerous, and rapid accurate diagnosis is essential to appropriately triage potentially surgical and irreversible conditions from patients for whom conservative management is sufficient. Diagnostic considerations include testicular torsion, torsion of testicular appendage, epididymoorchitis, epididymitis, idiopathic scrotal edema, hydrocele, inflammation of the tunica vaginalis, trauma, testicular tumors, epididymal cysts, Fournier gangrene, scrotal abscess, and strangulated inguinal hernia [3-6]. Torsion of a testicular appendage, epididymitis, and testicular torsion are the three most common causes of acute scrotal pain and account for approximately 85% to 90% of cases [7]. Large differential diagnoses and overlapping clinical presentation make the acute scrotum a diagnostic challenge.

Acute epididymoorchitis or epididymitis is the most common cause of acute scrotum in adolescent boys and adults [8,9]. In 2002, epididymitis or epididymoorchitis accounted for 1 in 44 outpatient visits in men 18 to 50 years of age [9,10]. Although uncommon in pediatric populations, it can be associated with urinary tract infections and/or structural and functional abnormalities of the urinary tract [11,12]. Epididymitis has a more insidious and gradual onset than testicular torsion. As inflammation and edema progress, a reactive hydrocele may develop making it difficult to differentiate from testicular torsion. Clinically, scrotal pain associated with epididymitis is usually

relieved when the testes are elevated over the symphysis pubis (the Prehn sign) [8,13]. This sign may help clinically differentiate between epididymitis and torsion of the spermatic cord, in which scrotal pain is not lessened with this maneuver [14].

Torsion of the testicular appendage is the most common etiology in prepubertal boys [5,12,15,16]. Clinical presentations such as focal tenderness over the upper pole of the testes and sudden onset of symptoms can overlap with the presentations of epididymitis and testicular torsion [12,16]. Infarction and necrosis of the appendage can be seen as a "blue dot sign," which is visualization of the infarcted appendage through the skin appearing as a blue dot. Albeit pathognomonic for appendage torsion [3,16], it is only seen in 21% of cases [17]. Scrotal edema develops rapidly, obscuring this finding on physical examination [18].

Testicular torsion is defined as twisting of the spermatic cord, compromising blood flow to and from the testes [2]. It is a surgical emergency with a bimodal distribution presenting more frequently in neonates and postpubertal boys than in adults, although it can occur at any age [19]. It has an estimated reported yearly incidence ranging from 2.9 to 3.8 in 100,000 boys <18 years of age [20,21]. Prompt recognition and surgical exploration within 6 to 8 hours after symptom onset is essential to prevent testicular loss [22]. A validated [23-26], clinical risk scoring system, Testicular Workup for Ischemia and Suspected Torsion Score, has shown high positive predictive value; however, it has not been widely adopted [20].

Special Imaging Considerations

Contrast-enhanced ultrasound (US) has expanded considerably in the last few decades and has proved to be a useful tool in determining the presence or absence of organ perfusion by improving the signal-to-noise ratio of tissue [27,28]. In principle it is able to detect and display echoes from individual bubbles, and therefore it is able to assess microvascularity, with an adverse event rate lower than or similar to that reported for other contrast agents [29-31]. On this basis, contrast-enhanced US can be considered as a possible problem-solving technique for diagnosing testicular torsion in children's small testicles in whom conventional Doppler methods fail to identify flow also in the contralateral side [32].

Microvascular imaging US is a new Doppler module that better differentiates slow flow via mathematical algorithms based on signal amplitude width [33], by separating low frequency of static tissue artifacts from low frequencies of very weak flow. Microvascular imaging obtains a higher resolution by separating the Doppler components of the 2 different sources [34].

Shear wave elastography (SWE) is a recently developed technique capable of quantitatively evaluating soft tissue stiffness [35,36]. This serves as a surrogate marker for tissue composition. Studies have shown that SWE values of testicular parenchyma increase during testicular torsion; however, there are limited studies showing whether these changes can be distinguished from other pathologies such as acute inflammation [36].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Adult or child. Acute onset of scrotal pain. Without trauma, without antecedent mass. Initial imaging.

This discussion will be limited to patients with acute pain, without history of trauma, and no history of antecedent or known scrotal or testicular mass because these scenarios are discussed elsewhere [37,38].

Variant 1: Adult or child. Acute onset of scrotal pain. Without trauma, without antecedent mass. Initial imaging.

A. CT Pelvis With IV Contrast

CT of the pelvis with intravenous (IV) contrast is not routinely used as an initial imaging modality for the evaluation of acute scrotal pain without trauma and without antecedent mass. There is no relevant literature regarding the use of CT of the pelvis in these patients. However, in the setting of Fournier's gangrene, CT can lead to early diagnosis with accurate assessment of disease extent [3].

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B. CT Pelvis Without and With IV Contrast

CT of the pelvis without and with IV contrast is not routinely used as an initial imaging modality for the evaluation of acute scrotal pain without trauma and without antecedent mass. There is no relevant literature regarding the use of CT of the pelvis in these patients.

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C. CT Pelvis Without IV Contrast

CT of the pelvis without IV contrast is not routinely used as an initial imaging modality for the evaluation of acute scrotal pain without trauma and without antecedent mass. There is no relevant literature regarding the use of CT of the pelvis in these patients.

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D. MRI Pelvis (Scrotum) Without and With IV Contrast

MRI of the pelvis without and with IV contrast is not routinely used as an initial imaging modality for the evaluation of acute scrotal pain without trauma and without antecedent mass. However, it may be used as a problem solving second-line modality when findings on US are indeterminate [39,40]. Diagnoses such as minor tunica albuginea tears and blunt scrotal trauma, chronic epididymoorchitis, and partial or intermittent torsion may sometimes be missed on US [39,41,42]. Due to its larger field of view and multiplanar capabilities, MRI of the scrotum provides excellent

anatomical detail of all scrotal contents and inguinal region. In addition, MRI provides high soft-tissue contrast, high sensitivity for contrast enhancement, and functional information. These features contribute to a more precise treatment strategy, reducing unwarranted surgical exploration [39,40,43-47]. Limitations of MRI in the evaluation of acute scrotum include long scan time, potentially delaying surgical exploration, and possible need for anesthesia in pediatric patients [39,40,48] and patients with claustrophobia or anxiety.

MRI has high accuracy in establishing the diagnosis of segmental testicular infarction [39,49-51]. Segmental testicular infarction is an uncommon entity that can mimic a small hypovascular tumor on US [50,52-55]. MRI findings include a T2 hypointense, avascular lesion with marked rim enhancement. Intralesional hyperintense T1 signal may coexist due to hemorrhagic products [39,44,50,55-57].

Dynamic contrast-enhanced MRI with subtraction imaging is highly sensitive and specific for the diagnosis of testicular torsion by characterizing testicular perfusion. According to a retrospective study of 39 patients (1–28 years of age) with acute scrotum, lack of contrast enhancement showed 100% specificity and 93% sensitivity for testicular torsion [58]. Other findings include spotty and/or streaky pattern of low or very low signal intensity on T2- and T2*-weighted images with 75% sensitivity for testicular torsion and 100% accuracy for testicular necrosis [59].

Diffusion-weighted imaging and apparent diffusion coefficient (ADC) provide qualitative and quantitative analysis by adding functional information about molecular activity and cellular function, in addition to the morphological information provided by other MRI sequences, like dynamic contrast-enhanced and T2- and T2*-weighted images [60,61]. Diffusion-weighted imaging and ADC images demonstrate lower ADC values of the torsed testicle compared to the normal contralateral testicle [62].

MRI has also been reported useful in the diagnosis of bell clapper deformity, an important risk factor for testicular torsion. MRI findings include hyperintense T2 signal between the posterior aspect of the epididymis and the scrotal wall, described as a "split sign," correlating with bell clapper deformity, with 83% sensitivity in a recent retrospective study [63].

Patients with acute scrotal infections and inflammation could benefit from further characterization of extent of disease and complications such as skin involvement and fistula formation, aiding in surgical planning or percutaneous drainage [37,39,64,65]. MRI's superior soft-tissue contrast resolution and larger field of view may be useful in patients with scrotal abscess, which may be difficult to differentiate from other entities such as testicular torsion, hematoma, or tumor on US [39,43,46,47,54,66,67]. MRI findings of scrotal abscess include T2 hyperintense fluid collection with variable T1 signal intensity and peripheral enhancement as well as testicular parenchymal enhancement and restricted diffusion on diffusion-weighted imaging with corresponding low signal on ADC map [44,64,65].

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E. MRI Pelvis (Scrotum) Without IV Contrast

MRI of the pelvis without IV contrast is not routinely used as an initial imaging modality for the evaluation of acute scrotal pain without trauma and without antecedent mass. There is no relevant literature regarding the use of MRI of the pelvis without IV contrast in these patients.

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F. Nuclear Medicine Scan Scrotum

Radionuclide scrotal imaging (RNSI) has been replaced by Doppler US as the primary imaging modality for evaluation of the acute scrotum. RNSI has a reported sensitivity and specificity for differentiation between testicular torsion and epididymoorchitis from 89% to 98% and 90% to 100%, respectively [68,69]. RNSI is limited by technical challenges in children whose small genitalia are difficult to image with radiotracers. RNSI also can have photon-deficient areas secondary to hydrocele, spermatocele, and inguinal hernias, which can be erroneously diagnosed as avascular testis [70].

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G. US Duplex Doppler Scrotum

Spectral analysis of the Doppler waveform allows a quantitative assessment of organ perfusion.

Arterial and venous flow are absent when there is complete testicular torsion of $>450^\circ$, making a sonographic diagnosis straightforward [71]. However, with partial or incomplete torsion, arterial flow is not necessarily absent because venous obstruction precedes arterial occlusion due to their thinner walls and lower pressure. The early manifestation of testicular torsion can be a diminished arterial velocity and a decreased diastolic flow with a consequently increased resistive index, indicating severe obstruction or occlusion of the venous outflow. Later, the diastolic flow can be absent or reversed [42,72]. Absent or reversed diastolic arterial flow can also be present with severe epididymitis or epididymoorchitis, with secondary venous outflow obstruction and subsequent venous infarction [73]. In a case series, partial testicular torsion was diagnosed after examination of the morphologic characteristics and amplitude of the spectral Doppler arterial waveform and its appearance relative to the contralateral testicle or a different region within the same testicle. Variability of the amplitude was the most common abnormality, followed by reversal of diastolic flow [6]. Additional characteristic spectral Doppler waveforms seen in partial testicular torsion include monophasic waveform, tardus-parvus morphology, and spectral Doppler waveform variations within the same testis, all worrisome for underlying ischemia. Spectral Doppler analysis should be performed in the upper, mid, and lower poles of each testicle [6,72,74].

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H. US Scrotum

US is the established first-line imaging modality for acute scrotal disease [75] and can be used to diagnose most scrotal disorders when combined with clinical history and physical examination. US is generally well tolerated and widely available, making it ideal for scrotal evaluation. High-resolution grayscale and color Doppler US allow prompt and accurate differentiation of scrotal emergencies [49,54,76,77].

Testicular perfusion can be evaluated with color Doppler, power Doppler, and spectral Doppler US [76]. Power Doppler is valuable in scrotal US because of its increased sensitivity to low-flow states and its independence from Doppler angle correction [76,78].

In testicular torsion, venous obstruction occurs first, followed by obstruction of arterial flow and ultimately by testicular ischemia. The extent of testicular ischemia depends on the degree of

torsion, which ranges from 180° to 720° or greater. The testicular salvage rate depends on the degree of torsion and the duration of ischemia [79]. Furthermore, torsion may be complete, incomplete, or transient. US findings include an enlarged heterogeneous testis that may be hypoechoic, ipsilateral hydrocele, skin thickening, and no color Doppler flow in the testis or spermatic cord [76]. However, in the first few hours of symptom onset it can also appear within normal limits [54,77]. The sensitivity and specificity of color Doppler US for the detection of testicular torsion is variable, with reports ranging from 69% to 96.8% and 87% to 100%, respectively [80-83]. False-negative Doppler evaluations (with sustained perfusion) can occur in the setting of partial torsion and spontaneous detorsion [77,82,84-87]. False-positive Doppler evaluation can be seen in infants and young boys who often have normally reduced intratesticular blood flow [71,77,88]. The contralateral asymptomatic testicle should be used as an internal control.

A twisted spermatic cord is the most specific US sign of torsion [89]. The "whirlpool sign" refers to a spiral twist of the spermatic cord that may be associated with a heterogeneously echogenic pseudomass below the point of torsion, seen on grayscale imaging. This pseudomass corresponds to a congested epididymis, vas deferens, and distal cord vessels [85,87,89,90].

US findings in patients with epididymitis include an enlarged and hypoechoic epididymis due to edema. Reactive hydroceles and scrotal wall thickening can also be seen. Color Doppler imaging shows increased blood flow corresponding to hyperemia, which is an important diagnostic feature of epididymitis. The sensitivity of color Doppler in detecting scrotal inflammation is nearly 100% [76,91]. The epididymis is the organ primarily involved in epididymoorchitis, with orchitis developing in 20% to 40% due to direct retrograde spread of infection [76]. Reperfusion after early ischemia, seen with torsion/detorsion, can induce a reactive hyperemia on color Doppler imaging, which is not sonographically distinguishable from the hyperemia seen with acute epididymoorchitis. Correlation with clinical data including presence of fever, waxing, and waning pain, as well as laboratory markers for infection must be integrated in the clinical assessment to distinguish both entities [54].

Summary of Recommendations

- **Variant 1:** US duplex Doppler scrotum and US scrotum is usually appropriate as the initial imaging for the acute onset of scrotal pain without trauma or antecedent mass in an adult or child. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria>.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
0	0 mSv	0 mSv
● (radioactive symbol)	<0.1 mSv	<0.03 mSv
● (radioactive symbol) ● (radioactive symbol)	0.1-1 mSv	0.03-0.3 mSv
● (radioactive symbol) ● (radioactive symbol) ● (radioactive symbol)	1-10 mSv	0.3-3 mSv
● (radioactive symbol) ● (radioactive symbol) ● (radioactive symbol) ● (radioactive symbol)	10-30 mSv	3-10 mSv
● (radioactive symbol)	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. Velasquez J, Boniface MP, Mohseni M. Acute Scrotum Pain: StatPearls Publishing, Treasure Island (FL); 2022.
2. Schick MA, Sternard BT. Testicular Torsion: StatPearls Publishing, Treasure Island (FL); 2022.
3. Bourke MM, Silverberg JZ. Acute Scrotal Emergencies. [Review]. Emergency Medicine Clinics of North America. 37(4):593-610, 2019 Nov.
4. Kyaw L, Choo CSC, Ong LY, Yap TL, Teo HJ, Nah SA. Management of acute testicular pain in children: changing trends with improvements in scrotal ultrasonography over 18 years. Singapore Medical Journal. 64(4):249-254, 2023 04.
5. Pogorelic Z, Mustapic K, Jukic M, et al. Management of acute scrotum in children: a 25-year single center experience on 558 pediatric patients. Can J Urol. 23(6):8594-8601, 2016 Dec.
6. Cassar S, Bhatt S, Paltiel HJ, Dogra VS. Role of spectral Doppler sonography in the evaluation of partial testicular torsion. J Ultrasound Med 2008;27:1629-38.
7. Carter CT, Brown A. Genitourinary Emergencies. In: Stone CK, Humphries RL, eds. CURRENT Diagnosis & Treatment: Emergency Medicine, 8e. New York, NY: McGraw-Hill Education; 2017.
8. Dogra V, Bhatt S. Acute painful scrotum. Radiol Clin North Am 2004;42:349-63.
9. Trojian TH, Lishnak TS, Heiman D. Epididymitis and orchitis: an overview. Am Fam Physician 2009;79:583-7.
10. NAMCS/NHAMCS - Ambulatory Health Care Data. Available at: <https://www.cdc.gov/nchs/ahcd/index.htm>.
11. Al-Taheini KM, Pike J, Leonard M. Acute epididymitis in children: the role of radiologic studies. Urology 2008;71:826-9; discussion 29.
12. Van Glabeke E, Khairouni A, Larroquet M, Audry G, Gruner M. Acute scrotal pain in children: results of 543 surgical explorations. Pediatr Surg Int 1999;15:353-7.
13. Noske HD, Kraus SW, Altinkilic BM, Weidner W. Historical milestones regarding torsion of the scrotal organs. J Urol 1998;159:13-6.
14. Jefferies MT, Cox AC, Gupta A, Proctor A. The management of acute testicular pain in children and adolescents. [Review]. BMJ. 350:h1563, 2015 Apr 02.
15. Makela E, Lahdes-Vasama T, Rajakorpi H, Wikstrom S. A 19-year review of paediatric patients with acute scrotum. Scand J Surg 2007;96:62-6.
16. Yang C Jr, Song B, Liu X, Wei GH, Lin T, He DW. Acute scrotum in children: an 18-year retrospective study. Pediatric Emergency Care. 27(4):270-4, 2011 Apr.
17. Boettcher M, Bergholz R, Krebs TF, Wenke K, Aronson DC. Clinical predictors of testicular torsion in children. Urology. 79(3):670-4, 2012 Mar.
18. Fujita N, Tambo M, Okegawa T, Higashihara E, Nutahara K. Distinguishing testicular torsion from torsion of the appendix testis by clinical features and signs in patients with acute scrotum. Res Rep Urol 2017;9:169-74.
19. Molokwu CN, Somani BK, Goodman CM. Outcomes of scrotal exploration for acute scrotal

- pain suspicious of testicular torsion: a consecutive case series of 173 patients. *BJU International*. 107(6):990-3, 2011 Mar.
- 20.** Lee LK, Monuteaux MC, Hudgins JD, et al. Variation in the evaluation of testicular conditions across United States pediatric emergency departments. *American Journal of Emergency Medicine*. 36(2):208-212, 2018 Feb.
- 21.** Zhao LC, Lautz TB, Meeks JJ, Maizels M. Pediatric testicular torsion epidemiology using a national database: incidence, risk of orchectomy and possible measures toward improving the quality of care. *Journal of Urology*. 186(5):2009-13, 2011 Nov.
- 22.** Mellick LB, Sinex JE, Gibson RW, Mears K. A Systematic Review of Testicle Survival Time After a Torsion Event. *Pediatric Emergency Care*. 35(12):821-825, 2019 Dec.
- 23.** Barbosa JABA, de Freitas PFS, Carvalho SAD, et al. Validation of the TWIST score for testicular torsion in adults. *International Urology & Nephrology*. 53(1):7-11, 2021 Jan.
- 24.** Barbosa JA, Tiseo BC, Barayan GA, et al. Development and initial validation of a scoring system to diagnose testicular torsion in children. *Journal of Urology*. 189(5):1859-64, 2013 May.
- 25.** Cabo J, Graham K, Chen H, et al. Increasing utilization of the TWIST score in workup of patients with acute scrotal pain: Role in diagnosis and risk stratification. *Journal of pediatric urology*. 18(6):845.e1-845.e8, 2022 12.
- 26.** Sheth KR, Keays M, Grimsby GM, et al. Diagnosing Testicular Torsion before Urological Consultation and Imaging: Validation of the TWIST Score. *Journal of Urology*. 195(6):1870-6, 2016 06.
- 27.** Jakobsen JA. Ultrasound contrast agents: clinical applications. *Eur Radiol* 2001;11:1329-37.
- 28.** Tang C, Fang K, Guo Y, et al. Safety of Sulfur Hexafluoride Microbubbles in Sonography of Abdominal and Superficial Organs: Retrospective Analysis of 30,222 Cases. *J Ultrasound Med* 2017;36:531-38.
- 29.** Appis AW, Tracy MJ, Feinstein SB. Update on the safety and efficacy of commercial ultrasound contrast agents in cardiac applications. *Echo Res Pract* 2015;2:R55-62.
- 30.** Piscaglia F, Bolondi L, Italian Society for Ultrasound in M, Biology Study Group on Ultrasound Contrast A. The safety of Sonovue in abdominal applications: retrospective analysis of 23188 investigations. *Ultrasound Med Biol* 2006;32:1369-75.
- 31.** Tenuta M, Sesti F, Bonaventura I, et al. Use of contrast enhanced ultrasound in testicular diseases: A comprehensive review. [Review]. *Andrology*. 9(5):1369-1382, 2021 09.
- 32.** Cantisani V, Bertolotto M, Weskott HP, et al. Growing indications for CEUS: The kidney, testis, lymph nodes, thyroid, prostate, and small bowel. [Review]. *European Journal of Radiology*. 84(9):1675-84, 2015 Sep.
- 33.** Malferrari G, Pulito G, Pizzini AM, et al. MicroV Technology to Improve Transcranial Color Coded Doppler Examinations. *J Neuroimaging* 2018;28:350-58.
- 34.** Visalli C, Mormina E, Tessitore A, et al. Acute scrotal pain in pediatric patients: diagnosis with an innovative Doppler technique (MicroV). *Emerg Radiol* 2021;28:209-14.
- 35.** Turna O, Alis D. A comparative study of shear wave elastography in the evaluation of undescended and retractile testes in a pediatric population. *J Med Ultrason* (2001).

46(2):231-237, 2019 Apr.

36. Xue E, Yu Y, Lin L, Li Z, Su H. Application value of real-time shear wave elastography in differential diagnosis of testicular torsion. *Medical Ultrasonography*. 22(1):43-48, 2020 03 01.
37. Khatri G, Bhosale PR, Robbins JB, et al. ACR Appropriateness Criteria® Newly Diagnosed Palpable Scrotal Abnormality. *J Am Coll Radiol* 2022;19:S114-S20.
38. Schieda N, Oto A, Allen BC, et al. ACR Appropriateness Criteria® Staging and Surveillance of Testicular Cancer: 2021 Update. *J Am Coll Radiol* 2022;19:S194-S207.
39. Tsili AC, Argyropoulou MI, Dolciami M, Ercolani G, Catalano C, Manganaro L. When to ask for an MRI of the scrotum. [Review]. *Andrology*. 9(5):1395-1409, 2021 09.
40. Tsili AC, Bertolotto M, Turgut AT, et al. MRI of the scrotum: Recommendations of the ESUR Scrotal and Penile Imaging Working Group. [Review]. *European Radiology*. 28(1):31-43, 2018 Jan.
41. Gotto GT, Chang SD, Nigro MK. MRI in the diagnosis of incomplete testicular torsion. *Br J Radiol* 2010;83:e105-7.
42. Sanelli PC, Burke BJ, Lee L. Color and spectral doppler sonography of partial torsion of the spermatic cord. *AJR Am J Roentgenol* 1999;172:49-51.
43. Cramer BM, Schlegel EA, Thueroff JW. MR imaging in the differential diagnosis of scrotal and testicular disease. *Radiographics* 1991;11:9-21.
44. Mittal PK, Abdalla AS, Chatterjee A, et al. Spectrum of Extratesticular and Testicular Pathologic Conditions at Scrotal MR Imaging. [Review]. *Radiographics*. 38(3):806-830, 2018 May-Jun.
45. Muglia V, Tucci S, Jr., Elias J, Jr., Trad CS, Bilbey J, Cooperberg PL. Magnetic resonance imaging of scrotal diseases: when it makes the difference. *Urology*. 2002; 59(3):419-423.
46. Parenti GC, Feletti F, Brandini F, et al. Imaging of the scrotum: role of MRI. *Radiol Med (Torino)*. 114(3):414-24, 2009 Apr.
47. Parenti GC, Feletti F, Carnevale A, Uccelli L, Giganti M. Imaging of the scrotum: beyond sonography. [Review]. *Insights Into Imaging*. 9(2):137-148, 2018 Apr.
48. Makela E, Lahdes-Vasama T, Ryymin P, et al. Magnetic resonance imaging of acute scrotum. *Scand J Surg*. 100(3):196-201, 2011.
49. Avery LL, Scheinfeld MH. Imaging of penile and scrotal emergencies. *Radiographics*. 33(3):721-40, 2013 May.
50. Fernandez-Perez GC, Tardaguila FM, Velasco M, et al. Radiologic findings of segmental testicular infarction. *AJR Am J Roentgenol*. 2005;184(5):1587-1593.
51. Kim W, Rosen MA, Langer JE, Banner MP, Siegelman ES, Ramchandani P. US MR imaging correlation in pathologic conditions of the scrotum. *Radiographics* 2007;27:1239-53.
52. Bilagi P, Sriprasad S, Clarke JL, Sellars ME, Muir GH, Sidhu PS. Clinical and ultrasound features of segmental testicular infarction: six-year experience from a single centre. *Eur Radiol*. 2007;17(11):2810-2818.
53. Sriprasad S, Kooiman GG, Muir GH, Sidhu PS. Acute segmental testicular infarction: differentiation from tumour using high frequency colour Doppler ultrasound. *Br J Radiol*

2001;74:965-7.

54. Sweet DE, Feldman MK, Remer EM. Imaging of the acute scrotum: keys to a rapid diagnosis of acute scrotal disorders. [Review]. *Abdominal Radiology*. 45(7):2063-2081, 2020 07.
55. Tsili AC, Bertolotto M, Rocher L, et al. Sonographically indeterminate scrotal masses: how MRI helps in characterization. [Review]. *Diagnostic & Interventional Radiology*. 24(4):225-236, 2018 Jul.
56. Mathur M, Mills I, Spektor M. Magnetic resonance imaging of the scrotum: pictorial review with ultrasound correlation. [Review]. *Abdominal Radiology*. 42(7):1929-1955, 2017 07.
57. Parenti GC, Sartoni M, Gaddoni E, Zago S, Campioni P, Mannella P. Imaging of segmental testicular infarction: our experience and literature review. [Review]. *Radiologia Medica*. 117(7):1161-75, 2012 Oct.
58. Terai A, Yoshimura K, Ichioka K, et al. Dynamic contrast-enhanced subtraction magnetic resonance imaging in diagnostics of testicular torsion. *Urology*. 2006;67(6):1278-1282.
59. Watanabe Y, Nagayama M, Okumura A, et al. MR imaging of testicular torsion: features of testicular hemorrhagic necrosis and clinical outcomes. *J Magn Reson Imaging*. 2007;26(1):100-108.
60. Balyan V, Das CJ, Sharma R, Gupta AK. Diffusion weighted imaging: Technique and applications. *World J Radiol* 2016;8:785-98.
61. Koh DM, Collins DJ. Diffusion-weighted MRI in the body: applications and challenges in oncology. *AJR Am J Roentgenol* 2007;188:1622-35.
62. Maki D, Watanabe Y, Nagayama M, et al. Diffusion-weighted magnetic resonance imaging in the detection of testicular torsion: feasibility study. *J Magn Reson Imaging*. 34(5):1137-42, 2011 Nov.
63. Tokuda B, Kiba M, Yamada K, et al. The split sign: The MRI equivalent of the bell clapper deformity. *British Journal of Radiology*. 92(1095):20180312, 2019 Mar.
64. Nicola R, Menias CO, Dahiya N, Robinson K, Hara AK, Siegel CL. Review of paratesticular pathology: findings on ultrasound and MRI. [Review]. *Abdominal Radiology*. 42(2):585-601, 2017 02.
65. Parker RA 3rd, Menias CO, Quazi R, et al. MR Imaging of the Penis and Scrotum. [Review]. *Radiographics*. 35(4):1033-50, 2015 Jul-Aug.
66. Gupta R, Allobaidi M, Jafri SZ, Bis K, Amendola M. Correlation of US and MRI findings of intratesticular and paratesticular lesions: from infants to adults. *Curr Probl Diagn Radiol* 2005;34:35-45.
67. O'Malley RB, Al-Hawary MM, Kaza RK, Wasnik AP, Liu PS, Hussain HK. Rectal imaging: part 2, Perianal fistula evaluation on pelvic MRI--what the radiologist needs to know. [Review]. *AJR Am J Roentgenol*. 199(1):W43-53, 2012 Jul.
68. Amini B, Patel CB, Lewin MR, Kim T, Fisher RE. Diagnostic nuclear medicine in the ED. [Review]. *Am J Emerg Med*. 29(1):91-101, 2011 Jan.
69. Melloul M, Paz A, Lask D, Manes A, Mukamel E. The value of radionuclide scrotal imaging in the diagnosis of acute testicular torsion. *Br J Urol*. 1995;76(5):628-631.
70. Hod N, Maizlin Z, Strauss S, Horne T. The relative merits of Doppler sonography in the

evaluation of patients with clinically and scintigraphically suspected testicular torsion. *Isr Med Assoc J.* 2004;6(1):13-15.

71. Lee FT, Jr., Winter DB, Madsen FA, et al. Conventional color Doppler velocity sonography versus color Doppler energy sonography for the diagnosis of acute experimental torsion of the spermatic cord. *AJR Am J Roentgenol* 1996;167:785-90.
72. Prando D. Torsion of the spermatic cord: the main gray-scale and doppler sonographic signs. *Abdom Imaging* 2009;34:648-61.
73. Dogra VS, Rubens DJ, Gottlieb RH, Bhatt S. Torsion and beyond: new twists in spectral Doppler evaluation of the scrotum. *J Ultrasound Med.* 2004;23(8):1077-1085.
74. Gupta A, Dogra V. Role of color flow Doppler ultrasound in the evaluation of acute scrotal pain. [Review]. *Andrology.* 9(5):1290-1297, 2021 09.
75. Sommers D, Winter T. The scrotum. In: Rumack CM, Levine D, eds. *Diagnostic Ultrasound.* 5th ed. Philadelphia, PA: Elsevier; 2018:chap 22.
76. Dogra VS, Gottlieb RH, Oka M, Rubens DJ. Sonography of the scrotum. *Radiology* 2003;227:18-36.
77. Sung EK, Setty BN, Castro-Aragon I. Sonography of the pediatric scrotum: emphasis on the Ts--torsion, trauma, and tumors. [Review]. *AJR. American Journal of Roentgenology.* 198(5):996-1003, 2012 May.
78. Hamper UM, DeJong MR, Caskey CI, Sheth S. Power Doppler imaging: clinical experience and correlation with color Doppler US and other imaging modalities. *Radiographics* 1997;17:499-513.
79. Guo X, Sun L, Lei W, Li S, Guo H. Management of testicular torsion <360degree in children: a single-center, retrospective study. *Journal of International Medical Research.* 48(4):300060519895861, 2020 Apr.
80. Boettcher M, Krebs T, Bergholz R, Wenke K, Aronson D, Reinshagen K. Clinical and sonographic features predict testicular torsion in children: a prospective study. *BJU Int.* 112(8):1201-6, 2013 Dec.
81. Burks DD, Markey BJ, Burkhard TK, Balsara ZN, Haluszka MM, Canning DA. Suspected testicular torsion and ischemia: evaluation with color Doppler sonography. *Radiology* 1990;175:815-21.
82. Kalfa N, Veyrac C, Lopez M, et al. Multicenter assessment of ultrasound of the spermatic cord in children with acute scrotum. *J Urol.* 2007;177(1):297-301; discussion 301.
83. Lam WW, Yap TL, Jacobsen AS, Teo HJ. Colour Doppler ultrasonography replacing surgical exploration for acute scrotum: myth or reality? *Pediatr Radiol.* 2005;35(6):597-600.
84. Altinkilic B, Pilatz A, Weidner W. Detection of normal intratesticular perfusion using color coded duplex sonography obviates need for scrotal exploration in patients with suspected testicular torsion. *J Urol.* 189(5):1853-8, 2013 May.
85. Baud C, Veyrac C, Couture A, Ferran JL. Spiral twist of the spermatic cord: a reliable sign of testicular torsion. *Pediatr Radiol* 1998;28:950-4.
86. Bentley DF, Ricchiuti DJ, Nasrallah PF, McMahon DR. Spermatic cord torsion with preserved testis perfusion: initial anatomical observations. *J Urol.* 2004;172(6 Pt 1):2373-2376.

87. Kalfa N, Veyrac C, Baud C, Couture A, Averous M, Galifer RB. Ultrasonography of the spermatic cord in children with testicular torsion: impact on the surgical strategy. *J Urol* 2004;172:1692-5; discussion 95.
88. Baker LA, Sigman D, Mathews RI, Benson J, Docimo SG. An analysis of clinical outcomes using color doppler testicular ultrasound for testicular torsion. *Pediatrics* 2000;105:604-7.
89. Vijayaraghavan SB. Sonographic differential diagnosis of acute scrotum: real-time whirlpool sign, a key sign of torsion. *J Ultrasound Med.* 2006;25(5):563-574.
90. Munden MM, Williams JL, Zhang W, Crowe JE, Munden RF, Cisek LJ. Intermittent testicular torsion in the pediatric patient: sonographic indicators of a difficult diagnosis. *AJR Am J Roentgenol.* 201(4):912-8, 2013 Oct.
91. Middleton WD, Siegel BA, Melson GL, Yates CK, Andriole GL. Acute scrotal disorders: prospective comparison of color Doppler US and testicular scintigraphy. *Radiology* 1990;177:177-81.
92. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://edge.sitecorecloud.io/americanoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf>.

Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

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