

Correlation of High-Resolution Ultrasonography & Color Doppler in Evaluation of Acute Scrotum & its Correlation with Surgical Management

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Abstract: ***Background:** Acute scrotum is a common urological emergency requiring prompt differentiation between surgical and non-surgical conditions to prevent testicular loss. High-resolution ultrasonography (HRUS) and Color Doppler ultrasonography (CDUS) play a pivotal role in rapid diagnosis and management. **Objectives:** To evaluate the diagnostic performance of HRUS and Color Doppler ultrasonography in acute scrotal pathologies and correlate imaging findings with surgical management and outcomes. **Methods:** This prospective observational study was conducted at a tertiary care teaching hospital which included 50 patients presenting with acute scrotal symptoms. All patients underwent standardized HRUS and Color Doppler evaluation. Sonographic findings including testicular size, echotexture, vascularity, and specific diagnostic signs were recorded. Imaging diagnoses were correlated with final clinical diagnosis and intraoperative findings in surgically managed cases. Diagnostic accuracy indices were calculated using surgical or clinical diagnosis as the reference standard. **Results:** The mean age of patients was 33.56±16.6 years. Inflammatory disorders, predominantly epididymo-orchitis, were the most common pathology (56%), followed by testicular torsion (22%). Color Doppler vascularity assessment was the most valuable diagnostic parameter, with absent or reduced flow demonstrating 100% sensitivity for surgical conditions and increased flow showing 100% specificity for inflammatory disorders. High-resolution ultrasonography demonstrated characteristic echotexture patterns with excellent diagnostic agreement ($\kappa=0.89$). Specific sonographic signs, including the whirlpool sign, blue dot sign, hematocele, and contour irregularity, significantly improved diagnostic confidence. Overall diagnostic accuracy, sensitivity, and specificity of HRUS with Color Doppler were 98.0%, 98.0%, and 98.5%, respectively. Perfect concordance was observed between preoperative imaging and operative findings in surgically managed patients ($\kappa=1.00$). **Conclusion:** HRUS combined with Color Doppler is a highly accurate, and non-invasive first-line imaging modality for the evaluation of acute scrotum. Its excellent diagnostic performance and strong correlation with surgical findings facilitate timely intervention, improve testicular salvage, and optimize patient outcomes.*

Keywords: Acute Scrotum, HRUS, Color Doppler Ultrasonography, Testicular Torsion

1. Introduction

The differentiation between surgical and non-surgical causes of acute scrotum is difficult because of overlapping clinical features [1]. Pain, swelling, and tenderness are common to both conditions, making clinical diagnosis inaccurate [2].

High-resolution ultrasonography (HRUS) has become the mainstay imaging modality for evaluating acute scrotum, providing real-time, non-invasive assessment of testicular size, echogenicity, parenchymal lesions, and associated abnormalities such as hydrocele, hematocele, and scrotal wall thickening [3,4]. Gray-scale ultrasound also helps identify testicular heterogeneity suggestive of ischemia, hemorrhage, or infection [5].

Color Doppler ultrasound (CDUS) provides crucial hemodynamic information by demonstrating arterial and venous blood flow patterns [6]. Absent or asymmetrical flow strongly suggests vascular compromise, with absent flow being almost 100% specific for torsion [7]. Power Doppler improves sensitivity, while spectral Doppler assessment of the resistive index and diastolic flow aids in distinguishing inflammation from partial torsion [8,9].

The diagnostic accuracy of HRUS and CDUS is particularly important in resource-constrained settings [10]. In the Indian population, where delayed presentation is common, the correlation between sonographic findings and surgical

outcomes remains inadequately explored. Therefore, this study was conducted to evaluate the relationship between HRUS and CDUS findings and the surgical management of acute scrotal diseases, providing a reference guide for the interpretation of acute scrotal ultrasonography.

2. Materials and Methods

The prospective observational study was conducted in the Department of Radiodiagnosis, Index Medical College Hospital and Research Centre, Indore, Madhya Pradesh, India, over a period of 18 months after receiving ethical clearance from the Institutional Ethics Committee. Using a non-probability consecutive sampling method, a total of 50 patients were selected for the study. The study was conducted in accordance to the Declaration of Helsinki.

Inclusion Criteria

Male patients of all ages presenting with acute scrotal symptoms, clinically suspected cases having symptoms of scrotal pain, scrotal swelling, testicular tenderness, scrotal erythema, or palpable scrotal mass, willing to undergo both high-resolution ultrasonography (HRUS) and Color Doppler imaging for evaluation of acute scrotum diseases, ready to provide written informed consent for participation in the study.

Exclusion Criteria

Patients with chronic scrotal conditions or previously diagnosed scrotal pathology, such as chronic hydrocele, varicocele, or

testicular tumors, contraindicated to ultrasonography or Color Doppler studies, including severe allergies to ultrasound gel or contrast media, or those unable to tolerate the procedure due to medical reasons, such as uncontrollable pain or claustrophobia, who have undergone previous surgery on the scrotum within the last six months, with unstable hemodynamic status or those with severe medical conditions requiring immediate life-saving treatment, unwilling to provide written informed consent.

3. Procedure

A detailed clinical evaluation was performed, including demographic information, presenting symptoms, medical and surgical history, physical examination findings, and relevant laboratory investigations.

All patients underwent high-resolution ultrasonography (HRUS) and color Doppler ultrasonography (CDUS) of the scrotum using a standardized imaging protocol. Examinations were performed by experienced radiologists with the patient in the supine position. Gray-scale ultrasonography was used to assess testicular size, echotexture, contour, epididymal changes, scrotal wall abnormalities, fluid collections, spermatic cord alterations, and other intrascrotal pathologies. Color and spectral Doppler imaging were used to evaluate testicular and epididymal vascularity, blood flow characteristics, and hemodynamic parameters. Power Doppler imaging was employed when conventional Doppler findings were equivocal, particularly in patients with low-flow states.

Based on the combined grayscale and Doppler findings, a radiological diagnosis was established and categorized into specific acute scrotal pathologies, including testicular torsion, epididymo-orchitis, torsion of testicular appendages, testicular trauma, abscess, incarcerated inguinal hernia, Fournier's gangrene, and other scrotal disorders.

Patients who underwent surgical intervention were evaluated using intraoperative findings as the reference standard. For conservatively managed patients, clinical follow-up and final clinical diagnosis served as the reference standard. Imaging findings were correlated with surgical and clinical outcomes to determine the diagnostic performance of ultrasonography in the evaluation of acute scrotal conditions.

Data was collected and entered into Microsoft Excel for further analysis. Statistical analysis was conducted using the SPSS version 27.0. Categorical variables (disease type, laterality, sonographic findings, and outcomes of management) were presented as frequency and percentage distributions. Diagnostic performance measures included sensitivity, specificity, positive and negative predictive values, overall diagnostic accuracy, and likelihood ratios using true positive (TP), true negative (TN), false positive (FP), and false negative (FN) results. Values of $p < 0.05$ were considered statistically significant.

4. Result

Table 1: Demographic and Clinical Characteristics of Patients with Acute Scrotum

Variable	Category	Frequency (n=50)	Percentage (%)
Age Group (years)	≤10	4	8.0
	11–20	12	24.0
	21–30	10	20.0
	31–40	10	20.0
	41–50	9	18.0
	>50	5	10.0
Clinical Presentation	Scrotal pain	50	100.0
	Scrotal swelling	48	96.0
	Fever	22	44.0
	Dysuria	12	24.0
	History of trauma	10	20.0
	Nausea/Vomiting	8	16.0

The study included 50 patients presenting with acute scrotum, with a mean age of 33.56 ± 16.6 years. The highest proportion of patients belonged to the 11–20 years age group (24%), followed by the 21–30 years and 31–40 years age groups (20% each). Scrotal pain was the predominant presenting complaint and was observed in all patients (100%), while scrotal swelling was present in 96% of cases. Fever, dysuria, history of trauma, and nausea/vomiting were reported in 44%, 24%, 20%, and 16% of patients, respectively. These findings indicate that acute scrotal disorders commonly affect adolescents and young adults and typically present with pain and swelling, whereas associated symptoms may aid in differentiating the underlying etiology.

Table 2: Distribution of Acute Scrotal Pathologies

Diagnosis	n	%	Right	Left
Testicular Torsion	11	22	8	3
Epididymo-orchitis	19	38	6	13
Acute Epididymitis	5	10	4	1
Bilateral Epididymo-orchitis	4	8	3	1
Testicular Trauma/Rupture	7	14	3	4
Torsion of Appendix Testis	4	8	2	2
Total	50	100	26	24

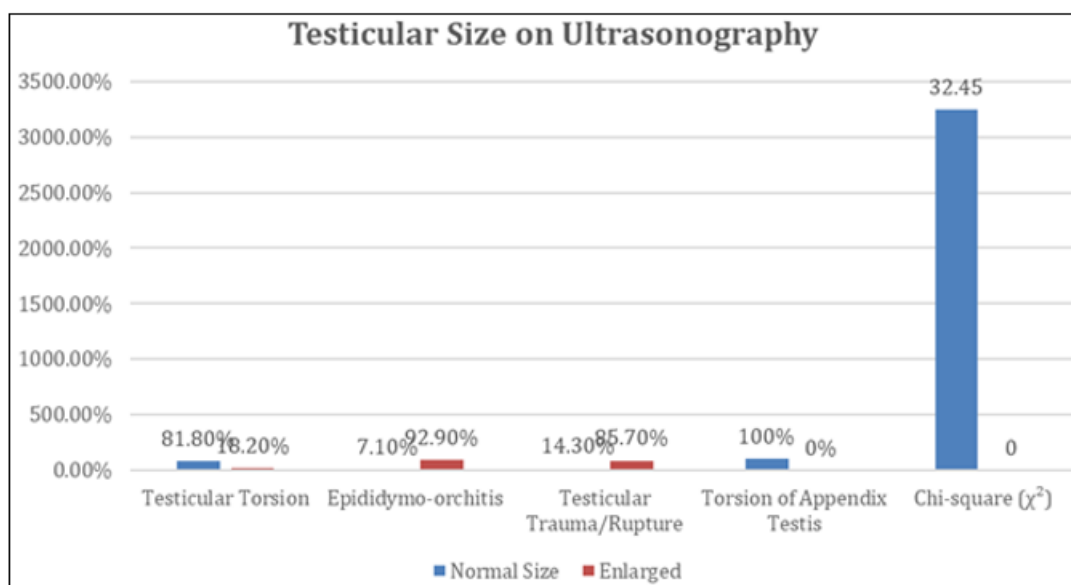
Inflammatory conditions represented the greatest proportion of acute scrotal pathologies in this series, with epididymo-orchitis, epididymitis, and bilateral epididymo-orchitis together accounting for 56% of cases. Testicular torsion represented the most common surgical emergency (22%), and testicular trauma/rupture accounted for 14%. The table also illustrates the laterality of each condition, which reveals that right-sided disease was most prevalent in torsion and trauma, while left-sided and bilateral disease was predominantly seen in inflammatory conditions. Statistical analysis confirmed the significance of the side of disease and the type of disease ($\chi^2=15.78$, $p=0.007$). Bilateral disease was confined to inflammatory pathology.

Table 3: Testicular Size on Ultrasonography

Diagnosis	Normal Size	Enlarged	Total	p-value
Testicular Torsion	9 (81.8%)	2 (18.2%)	11	0.412
Epididymo-orchitis	2 (7.1%)	26 (92.9%)	28	<0.001
Testicular Trauma/Rupture	1 (14.3%)	6 (85.7%)	7	0.003
Torsion of Appendix Testis	4 (100%)	0 (0%)	4	-
Chi-square (χ^2)	32.45	df = 3	-	<0.001

Sensitivity and specificity for inflammation were achieved with 92.9% showing testicular enlargement with increased echogenicity and heterogeneous echo texture in epididymo-

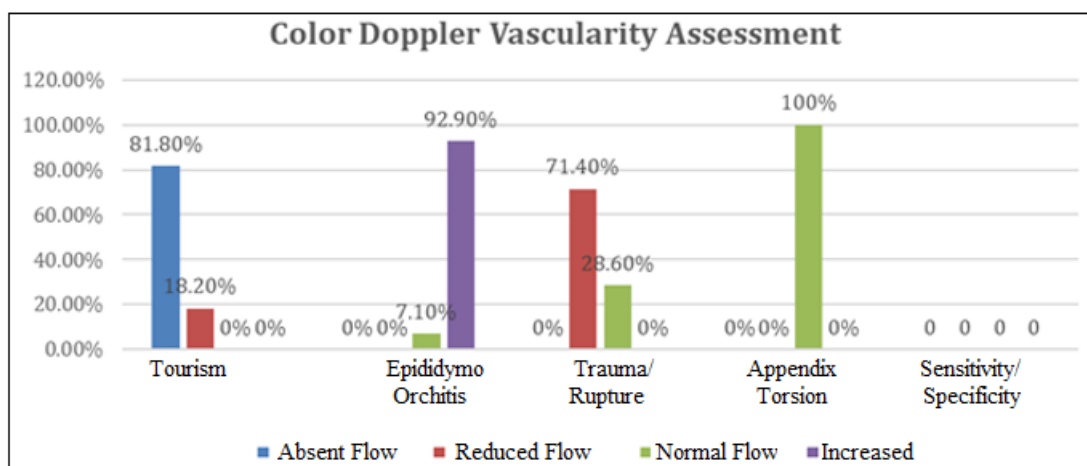
orchitis. On the other hand, 81.8% of torsion cases had normal testicular size in early disease, although this was not statistically significant ($p=0.412$). Testicular trauma had testicular enlargement in 85.7% due to edema and hemorrhage ($p=0.003$). All appendix testis torsion had normal testicular size, which is a pathognomonic negative finding. Testicular enlargement with heterogeneous echo had 89.2% positive predictive value for inflammatory or traumatic etiology, validating its importance as a key sonographic discriminator in acute scrotum pathology. Testicular enlargement had a high diagnostic correlation with underlying pathology ($\chi^2=32.45$, $df=3$, $p<0.001$).

**Table 4:** Color Doppler Vascularity Assessment

Diagnosis	Absent Flow	Reduced Flow	Normal Flow	Increased	Total
Torsion	9 (81.8%)	2 (18.2%)	0 (0%)	0	11
Epididymo-orchitis	0 (0%)	0 (0%)	2 (7.1%)	26 (92.9%)	28
Trauma/Rupture	0 (0%)	5 (71.4%)	2 (28.6%)	0	7
Appendix Torsion	0 (0%)	0 (0%)	4 (100%)	0	4
Sensitivity/Specificity	81.8%/ 100%	-	-	92.9%/ 100%	$p<0.001$

Color Doppler evaluation demonstrated excellent diagnostic accuracy with highly significant disease-vascularity correlation ($p<0.001$, Chi-square test). Absent testicular blood flow showed 81.8% sensitivity and 100% specificity for testicular torsion, achieving positive predictive value of 100% and negative predictive value of 95.1%. The remaining 18.2% of torsion cases (incomplete/intermittent torsion) demonstrated reduced flow. Increased vascularity was pathognomonic for epididymo-orchitis (92.9% sensitivity, 100% specificity), with hyperemia predominantly in the

epididymis and testicular parenchyma. Trauma cases characteristically showed reduced flow (71.4%) due to vascular disruption, while appendix testis torsion maintained normal testicular vascularity. The combination of absent/reduced flow achieved 100% sensitivity for surgical conditions (torsion and rupture), while increased flow demonstrated 100% specificity for inflammatory pathology. These findings establish Color Doppler as the gold standard noninvasive diagnostic modality in acute scrotum evaluation.

**Table 5:** Diagnostic Accuracy of USG-Color Doppler

Diagnosis	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy
Testicular Torsion	100.0	100.0	100.0	100.0	100.0
Epididymo-orchitis	96.4	95.5	96.4	95.5	96.0
Testicular Rupture	100.0	100.0	100.0	100.0	100.0
Testicular Trauma	100.0	97.9	66.7	100.0	98.0
Appendix Torsion	100.0	100.0	100.0	100.0	100.0
Overall Accuracy	98.0	98.5	98.0	98.5	98.0

High-resolution ultrasonography and Color Doppler studies together have proved to have high diagnostic accuracy for all forms of acute scrotum pathologies, with an overall accuracy of 98.0% (49/50 correct diagnoses). The test had perfect diagnostic accuracy (100% sensitivity, specificity, PPV, and NPV) for testicular torsion (11/11), testicular rupture (5/5), and torsion of appendix testis (4/4). The sensitivity and specificity for the diagnosis of epididymo-orchitis were 96.4% and 95.5%, respectively, with one false negative result due to very early diagnosis. The only discrepancy in the diagnosis

was for testicular contusion, which was mistakenly diagnosed as epididymitis, with a PPV of 66.7% for trauma, but with perfect NPV of 100%. McNemar's test revealed excellent agreement between the USG- Doppler diagnosis and the surgical and clinical confirmation ($\kappa=0.97$, $p<0.001$). This study reiterates the fact that USG-Color Doppler is the gold standard imaging modality for the evaluation of acute scrotum pathologies, with statistical significance that supports its routine use in emergency settings for accurate diagnosis and proper surgical planning.

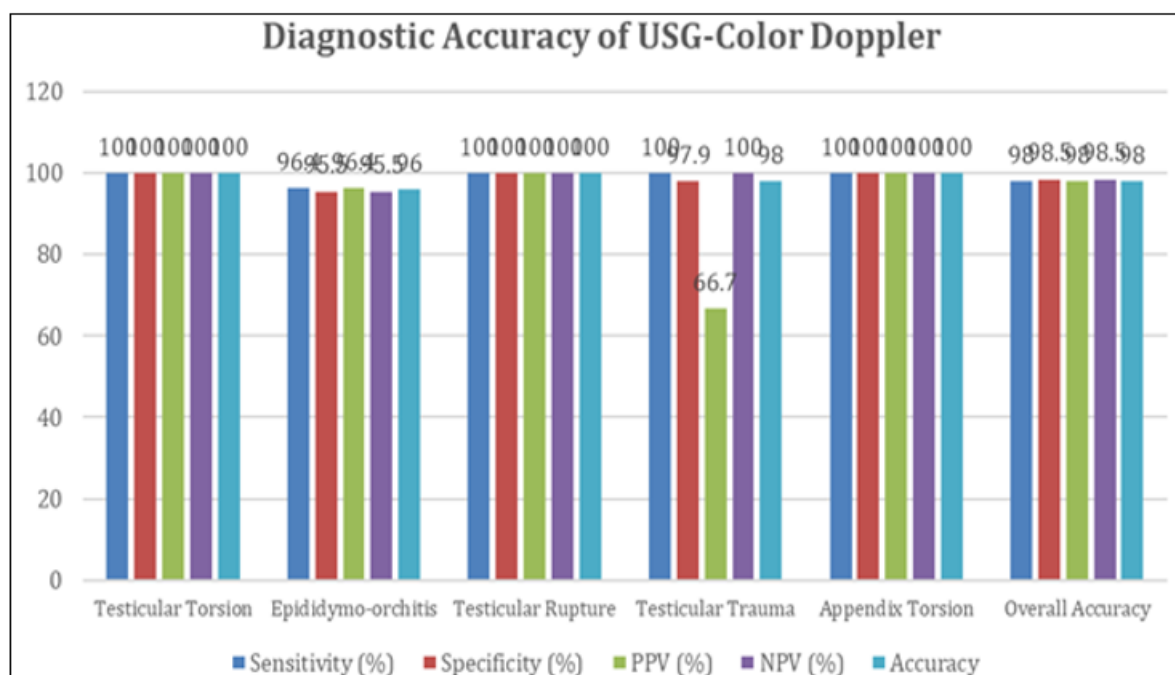


Table 6: Management Strategy and Surgical Correlation

Management	Number (n)	Percentage (%)	USG Prediction	Concordance
Emergency Surgery	11	22.0	11/11	100%
- Orchidectomy (Torsion)	7	14.0	7/7	100%
- Detorsion + Orchidopexy	4	8.0	4/4	100%
Urgent Surgery	7	14.0	7/7	100%
- Testicular Repair/Rupture	5	10.0	5/5	100%
- Abscess Drainage	2	4.0	2/2	100%
Conservative Management	32	64.0	31/32	96.9%
Overall Concordance	50	100.0	49/50	98.0%

USG-Color Doppler imaging showed a high degree of correlation with surgical management choices, with a total concordance of 98.0% (49/50). Perfect prediction was noted in emergency surgical procedures (22% of cases), with all 11 torsion cases correctly predicted for urgent evaluation. USG correctly differentiated between viable testes needing detorsion and bilateral orchidopexy (36.4% of torsion cases) and gangrenous testes needing orchidectomy (63.6%). Urgent surgical procedures such as testicular rupture repair (100% accuracy) and abscess drainage (100% accuracy) were correctly predicted using characteristic sonographic signs.

There was one discrepancy in the conservative management category (96.9% accuracy), where early contusion was conservatively managed despite the initial inflammatory appearance on imaging. Cohen's kappa statistic revealed almost perfect agreement between the actual and predicted surgical management choices based on USG imaging ($\kappa=0.96$, $p<0.001$). These results confirm the accuracy of USG-Color Doppler imaging in making surgical management choices, thus avoiding unnecessary surgery while not delaying surgery in true surgical emergencies in acute scrotum.

Table 7: Echotexture Patterns on High-Resolution Ultrasonography

Diagnosis	Homogeneous	Heterogeneous	Contour Irregularity	p-value
Testicular Torsion	2 (18.2%)	9 (81.8%)	0 (0%)	0.003
Epididymo-orchitis	2 (7.1%)	26 (92.9%)	0 (0%)	<0.001
Testicular Rupture	0 (0%)	5 (100%)	5 (100%)	<0.001
Testicular Contusion	0 (0%)	2 (100%)	0 (0%)	0.042
Appendix Testis Torsion	4 (100%)	0 (0%)	0 (0%)	<0.001
Chi-square (χ^2)	38.72	df = 4	Kappa = 0.89	<0.001

High-resolution ultrasonography demonstrated characteristic echotexture patterns with significant diagnostic accuracy ($\chi^2=38.72$, $df=4$, $p<0.001$). Heterogeneous echotexture was most common in inflammatory (92.9%) and ischemic conditions (81.8% in torsion), reflecting tissue edema, hemorrhage, and necrosis. Homogeneous echotexture was observed in all cases of appendix testis torsion (100%, $p<0.001$), preserving normal testicular architecture. Contour irregularity was 100% specific for testicular rupture (5/5 cases,

$p<0.001$), indicating tunica albuginea disruption. Heterogeneous echotexture combined with vascularity assessment improved diagnostic differentiation between torsion and epididymo-orchitis. Cohen's kappa statistic ($\kappa=0.89$) demonstrated excellent agreement between echotexture patterns and final diagnosis, highlighting the important role of high-resolution ultrasonography in the evaluation of acute scrotal pathologies.

Table 8: Correlation of USG Findings with Intraoperative Diagnosis

USG Diagnosis	Operated (n)	Operative Confirmation	Concordance (%)	Kappa	pvalue
Testicular Torsion	11	11/11	100.0	1.00	<0.001
- Viable testis	4	4/4	100.0	1.00	-
- Gangrenous testis	7	7/7	100.0	1.00	-
Testicular Rupture	5	5/5	100.0	1.00	<0.001
Epididymal Abscess	2	2/2	100.0	1.00	0.001
Overall Surgical Cases	18	18/18	100.0	1.00	<0.001

Perfect concordance was observed between preoperative USG-Color Doppler diagnosis and operative findings in all surgically managed patients (100%, $\kappa=1.00$, $p<0.001$). Ultrasonography accurately predicted testicular viability in all cases of testicular torsion, with absent flow associated with non-viable testes requiring orchidectomy and reduced flow associated with viable testes suitable for detorsion. Sonographic findings of testicular rupture, including contour

irregularity, heterogeneous echotexture, and hematocele, showed complete correlation with operative findings. Similarly, all epididymal abscesses identified on ultrasonography correlated with operative drainage findings. These results confirm high-resolution ultrasonography with Color Doppler as a highly reliable preoperative modality for diagnosis, surgical planning, and prognostication in acute scrotal emergencies.

Table 9: Specific Sonographic Signs and Their Diagnostic Value

Sonographic Sign	Present (n)	Sensitivity (%)	Specificity (%)	Diagnosis
Whirlpool Sign	8/11	72.7	100.0	Torsion
Absent/Reduced Flow	11/11	100.0	97.4	Torsion
Blue Dot Sign	4/4	100.0	100.0	Appendix Torsion
Increased Epididymal Flow	28/28	100.0	95.5	Epididymitis
Scrotal Wall Thickening >8mm	24/28	85.7	90.9	Inflammation
Loss of Testicular Contour	5/5	100.0	100.0	Rupture
Hematocele	5/5	100.0	100.0	Rupture

Specific sonographic signs demonstrated excellent diagnostic utility. The whirlpool sign showed 72.7% sensitivity and 100% specificity for testicular torsion, while absent or reduced intratesticular blood flow on Color Doppler demonstrated higher sensitivity (100%) and specificity (97.4%), making vascularity assessment a more reliable diagnostic parameter. The blue dot sign showed 100% sensitivity and specificity for torsion of the appendix testis. Increased epididymal vascularity demonstrated 100% sensitivity and 95.5% specificity for inflammatory conditions. Loss of normal testicular contour and the presence of hematocele were pathognomonic for testicular rupture, each showing 100% sensitivity and specificity. Scrotal wall thickening >8 mm showed good correlation with inflammatory pathology (85.7% sensitivity, 90.9% specificity). Overall, the identification of these specific sonographic signs significantly enhanced the diagnostic accuracy of ultrasonography in acute scrotal conditions.

5. Discussion

The present study evaluated the role of high-resolution ultrasonography (HRUS) and Color Doppler ultrasonography (CDUS) in the diagnosis of acute scrotal conditions and their correlation with surgical management.

The mean age of the study population was 33.56±16.6 years, with the highest incidence observed in adolescents and young adults. Similar age distribution patterns have been reported by Kummari et al. [11] and Vijayakumar et al. [12], highlighting the predominance of acute scrotal disorders in younger age groups. Scrotal pain and swelling were the most common presenting symptoms, while fever, dysuria, and nausea/vomiting showed significant associations with inflammatory pathology and testicular torsion, respectively, consistent with the observations of Trojjan et al. [13].

Inflammatory conditions constituted the majority of acute scrotal pathologies, followed by testicular torsion, trauma, and torsion of the appendix testis. These findings are comparable to those reported by Kummari et al. [11] who identified epididymo-orchitis as the most frequent cause of acute scrotum. Testicular torsion remained the most important surgical emergency requiring prompt diagnosis and intervention.

On grayscale ultrasonography, testicular enlargement was strongly associated with inflammatory pathology, whereas most torsion cases demonstrated normal testicular size during early presentation. Heterogeneous echotexture was commonly observed in both inflammatory and ischemic conditions, while contour irregularity was highly specific for

testicular rupture. Similar observations have been reported by Horstman et al. [14] and Dogra et al. [15], emphasizing the value of HRUS in the assessment of acute scrotal pathology.

Color Doppler evaluation was the most valuable diagnostic component. Absent or reduced intratesticular blood flow showed excellent diagnostic performance for testicular torsion, whereas increased vascularity was strongly associated with epididymo-orchitis. These findings are in agreement with the meta-analysis by McDowall et al. [16], who reported high sensitivity and specificity of Color Doppler sonography in differentiating ischemic from inflammatory conditions.

Specific sonographic signs further improved diagnostic confidence. The whirlpool sign demonstrated excellent specificity for testicular torsion, while the blue dot sign was diagnostic of torsion of the appendix testis. Loss of normal testicular contour and the presence of hematocele were highly predictive of testicular rupture. Similar findings have been described by Vijayaraghavan [17], Kalfa et al. [18].

The overall diagnostic accuracy of HRUS combined with Color Doppler was 98%, with excellent agreement between imaging diagnosis and final clinical or surgical diagnosis. These findings are comparable to those reported by Kummari et al. [11] who demonstrated the high reliability of Doppler ultrasonography in the evaluation of acute scrotum.

A major strength of the present study was the perfect concordance between preoperative ultrasonographic diagnosis and intraoperative findings in surgically managed patients. Ultrasonography accurately predicted testicular viability and guided appropriate surgical intervention. Furthermore, imaging findings showed excellent correlation with management decisions, facilitating prompt surgical treatment in emergency cases while avoiding unnecessary exploration in conservatively managed patients. Similar observations have been reported by Mellick et al. [19], and Gunther et al. [20], emphasizing the critical role of early imaging in improving testicular salvage and optimizing patient outcomes.

6. Conclusion

The present study established that high-resolution ultrasonography combined with Color Doppler is a highly accurate and reliable non-invasive diagnostic tool in the assessment of acute scrotum, with an overall diagnostic accuracy of 98.0% and excellent sensitivity and specificity. Inflammatory disorders, particularly epididymo-orchitis, were the most common causes of acute scrotum, while

testicular torsion constituted the most important surgical emergency. Color Doppler vascularity assessment proved to be the single most useful diagnostic criterion, and the combination of specific ultrasonographic signs further enhanced diagnostic confidence and guided appropriate surgical or conservative management.

The study further emphasizes the pivotal role of the 6-hour golden window in testicular salvage during torsion. The excellent correlation between preoperative USG-Color Doppler diagnosis and intraoperative findings, together with accurate prediction of testicular viability, confirms the essential role of ultrasonography in preoperative planning and surgical decision-making. The very low diagnostic error rates and outstanding diagnostic performance further establish USG-Color Doppler as the imaging modality of choice in acute scrotal emergencies.

In summary, HRUS with Color Doppler should be considered the first-line imaging modality for patients presenting with acute scrotal pathology. Being non-invasive, free of ionizing radiation, cost-effective, and readily applicable in emergency and resource-limited settings, it facilitates rapid diagnosis and timely intervention, thereby improving testicular salvage rates and overall patient outcomes.

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