

## Research Article

# EVALUATION OF SCROTAL PATHOLOGIES BY ULTRASOUND AND COLOUR DOPPLER.

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### Article History

**Received:** 25.04.2026

**Revised:** 08.05.2026

**Accepted:** 22.05.2026

**Published:** 09.06.2026

### Citations:

Chandra S, Mendiratta KK, Prabha T, Ahlawat D, Waquar S, Sukhani PK. Evaluation of scrotal pathologies by ultrasound and colour Doppler. J Surg Radiol, 5(6) 189-198.

**Abstract:** *Introduction:* Scrotal pathologies present with overlapping clinical features, making accurate diagnosis challenging, particularly in acute conditions where timely intervention is crucial. Ultrasonography (USG) with colour Doppler imaging plays a key role in non-invasive evaluation. *Objective:* To evaluate the role of grayscale ultrasonography and colour Doppler in assessing scrotal pathologies and to determine their efficacy in differentiating testicular from extra-testicular lesions and acute from chronic conditions. *Methods:* This hospital-based observational study was conducted on 200 male patients with suspected scrotal pathology. All patients underwent grayscale ultrasonography followed by colour and spectral Doppler evaluation. Lesions were characterized based on morphology and vascular patterns. Statistical analysis was performed using appropriate tests, with  $p < 0.05$  considered significant. *Results:* The majority of patients were in the 31–40 years age group, with swelling and pain being the most common presentation. Extra-testicular lesions (52.5 %) were more frequent than testicular lesions (47.5 %). Inflammatory conditions constituted the largest diagnostic group. Increased vascularity with low-resistance flow was strongly associated with inflammatory pathology, whereas reduced or absent flow was indicative of torsion. Colour Doppler demonstrated high diagnostic accuracy (>90%) in differentiating torsion from inflammatory conditions. *Conclusion:* Ultrasonography combined with colour Doppler is a highly reliable, non-invasive modality for comprehensive evaluation of scrotal pathologies, enabling accurate diagnosis and guiding appropriate management.

**Keywords:** Scrotal pathologies; Ultrasonography; Colour Doppler; Testicular torsion; Epididymo-orchitis; Varicocele; Acute scrotum .

## INTRODUCTION

Scrotal pathologies encompass a wide spectrum of congenital, inflammatory, vascular, neoplastic, and traumatic conditions affecting the testes, epididymis, spermatic cord, and surrounding structures. These disorders represent a significant proportion of urological and radiological consultations and may present with overlapping clinical features such as pain, swelling, tenderness, or a palpable mass, making accurate clinical differentiation challenging<sup>1</sup>. Prompt and precise diagnosis is essential, particularly in acute conditions such as testicular torsion, where delayed intervention may result in irreversible ischemic damage and loss of the testis<sup>2</sup>.

The epidemiology of scrotal diseases varies across age groups and geographic regions. Testicular tumours account for approximately 1–2% of all male malignancies but represent the most common solid malignancy in men aged 15–35 years<sup>3</sup>. Varicocele is observed in nearly 15% of the general male population

and up to 40% of infertile men, highlighting its clinical relevance in reproductive health<sup>4</sup>. In developing countries, infectious etiologies such as epididymo-orchitis remain highly prevalent, often associated with delayed presentation and increased risk of complications such as infertility and testicular atrophy<sup>5</sup>. These epidemiological trends underscore the need for accessible, reliable, and non-invasive diagnostic modalities.

Historically, evaluation of scrotal pathologies relied heavily on clinical examination, which has limited sensitivity and specificity, particularly in acute scrotal conditions<sup>6</sup>.

The advent of ultrasonography (USG) revolutionized the diagnostic approach by enabling real-time visualization of scrotal anatomy. High-resolution grayscale ultrasonography allows accurate assessment of testicular size, echotexture, and focal lesions, while also distinguishing intratesticular from extratesticular pathology—a critical determinant of malignancy risk<sup>7</sup>. Intratesticular solid lesions are considered malignant

until proven Otherwise, whereas extratesticular lesions are predominantly benign<sup>8</sup>.

The integration of colour Doppler ultrasonography (CDUS) has further enhanced diagnostic accuracy by enabling evaluation of vascular perfusion and hemodynamic changes. Doppler assessment plays a pivotal role in differentiating ischemic from inflammatory conditions, particularly in the setting of acute scrotal pain<sup>9</sup>. In testicular torsion, reduced or absent intratesticular blood flow is the hallmark finding, whereas inflammatory conditions such as epididymo-orchitis demonstrate increased vascularity due to hyperaemia<sup>10</sup>. Early identification of these vascular patterns is critical, as testicular salvage rates decline significantly beyond six hours of torsion onset<sup>11</sup>.

Recent advancements in ultrasound technology, including high-frequency transducers (12–18 MHz), power Doppler, and microvascular imaging techniques, have further improved sensitivity in detecting subtle parenchymal and vascular abnormalities<sup>12</sup>. These developments allow better characterization of scrotal lesions, including small intratesticular tumours, early inflammatory changes, and low-flow states seen in partial torsion<sup>13</sup>. Additionally, spectral Doppler parameters such as resistive index (RI) and pulsatility index (PI) provide quantitative assessment of vascular resistance, aiding in differentiation between various pathological conditions<sup>14</sup>.

Ultrasonography also plays a crucial role in evaluating chronic scrotal conditions. Varicocele, a leading cause of male infertility, is accurately diagnosed using Doppler criteria such as venous diameter and reflux duration during the Valsalva manoeuvre<sup>15</sup>. Similarly, hydrocele, epididymal cysts, and scrotal hernias are readily identified on grayscale imaging, often eliminating the need for further imaging<sup>16</sup>. In scrotal trauma, ultrasound combined with Doppler assessment reliably determines testicular integrity and viability, guiding surgical decision-making<sup>17</sup>.

Despite the availability of other imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT), ultrasonography remains the first-line investigation for scrotal pathologies due to its non-invasive nature, lack of ionizing radiation, cost-effectiveness, and real-time capability<sup>18</sup>. MRI is reserved for problem-solving in indeterminate cases, while CT is primarily used for staging of malignancies rather than primary evaluation<sup>19</sup>.

Multiple studies have demonstrated the high diagnostic accuracy of combined grayscale and Doppler ultrasonography in scrotal diseases. Sensitivity rates exceeding 90% have been reported for differentiating torsion from inflammatory conditions, with strong correlation to surgical and histopathological findings<sup>20</sup>. However, limitations such as operator

dependency, variability in Doppler parameters, and challenges in early or partial torsion persist<sup>21</sup>. Furthermore, most available data are derived from Western populations, and there remains a need for region-specific studies reflecting local disease patterns and healthcare settings.

In the Indian context, where infectious and inflammatory scrotal pathologies are more prevalent and access to advanced imaging may be limited, ultrasonography with colour Doppler serves as an indispensable diagnostic tool<sup>22</sup>. Nevertheless, variability in clinical presentation, demographic factors, and imaging practices necessitates continuous evaluation to optimize diagnostic protocols and improve patient outcomes.

Therefore, the present study aims to comprehensively evaluate the role of ultrasonography and colour Doppler in the assessment of scrotal pathologies, to correlate imaging findings with clinical presentation, and to determine the diagnostic efficacy of these modalities in differentiating testicular and extratesticular lesions as well as acute and chronic scrotal conditions. By providing locally relevant data and reinforcing evidence-based imaging strategies, this study seeks to enhance diagnostic accuracy, reduce unnecessary surgical interventions, and improve overall management of scrotal diseases.

## MATERIALS AND METHODS

**Study Design and Setting:** This hospital-based observational study was conducted in the Department of Radiodiagnosis at Mahatma Gandhi Medical College and Hospital (MGMC), Jaipur, a tertiary care teaching institution catering to both urban and rural populations. The study was designed to evaluate the role of grayscale ultrasonography and colour Doppler imaging in the assessment of scrotal pathologies. The study duration extended over a period of 18 months, from April 2024 (following approval from the Institutional Ethics Committee) to September 2025.

**Study Population and Sampling Technique:** The study population comprised male patients of all age groups presenting with clinically suspected scrotal pathology who were referred to the Department of Radiodiagnosis from the General Surgery and Urology departments. A total of 200 patients were included in the study, in accordance with the approved sample size. A consecutive sampling technique was employed, wherein all eligible patients fulfilling the inclusion criteria during the study period were enrolled until the required sample size was achieved. Written informed consent was obtained from all participants prior to inclusion in the study. In paediatric cases, assent along with guardian consent was obtained.

**Inclusion and Exclusion Criteria:** Male patients of any age presenting with scrotal pain, swelling, or palpable

mass and those referred for ultrasonography and/or colour Doppler evaluation of the scrotum were included in the study. Patients who provided informed consent were enrolled. Patients unwilling to participate, those with a history of prior scrotal surgery resulting in distorted anatomy, and cases with inadequate imaging due to poor cooperation or technical limitations were excluded from the study.

#### **Study Equipment and Imaging Protocol:**

Ultrasonography and colour Doppler examinations were performed using high-resolution ultrasound systems, including WIPRO GE LOGIQ P9, GE LOGIQ S8, Samsung HS50, Philips Affiniti 30, and Siemens Acuson X300 machines, equipped with high-frequency linear transducers. All examinations were conducted with the patient in the supine position, with appropriate scrotal support to ensure. Optimal visualization and patient comfort. Bilateral scrotal evaluation was performed in all cases to allow comparison with the contralateral side.

**Clinical Assessment and Data Collection:** A detailed clinical history was recorded for each patient, including age, presenting complaints, duration and onset of symptoms, and relevant medical or surgical history. Clinical findings were documented systematically prior to imaging. Data were recorded using a structured proforma to ensure uniformity in data collection across all cases.

**Grayscale Ultrasonography Evaluation:** Grayscale ultrasonography was performed to assess the morphology of the scrotal contents. The parameters evaluated included testicular size, shape, and echotexture; presence of focal or diffuse lesions; epididymal size and echotexture; and associated findings such as hydrocele, haematocele, or scrotal wall thickening. Lesions were categorized as testicular or extra-testicular based on their anatomical origin. Particular attention was paid to identifying cystic versus solid lesions, presence of calcifications, and changes in parenchymal echogenicity.

**Colour and Spectral Doppler Assessment:** Colour Doppler imaging was utilized to evaluate vascularity of the testes and epididymis, symmetry of blood flow between both sides, and the presence of hyperaemia or reduced/absent perfusion. Spectral Doppler analysis was performed wherever applicable to measure vascular indices, including resistive index (RI) and pulsatility index (PI). These parameters were used to assess

vascular resistance and aid in differentiating ischemic from inflammatory conditions. In suspected cases of varicocele, Doppler evaluation was performed both at rest and during the Valsalva manoeuvre to detect venous reflux.

**Diagnostic Criteria:** Standard diagnostic criteria were applied for various scrotal pathologies. Testicular torsion was diagnosed based on reduced or absent intratesticular blood flow compared to the contralateral testis. Acute epididymo-orchitis was identified by hypoechoic changes in echotexture with increased vascularity and low-resistance flow. Chronic epididymo-orchitis was characterized by heterogeneous echotexture with normal or reduced vascularity and high-resistance flow. Varicocele was diagnosed when dilated pampiniform plexus veins measuring more than 2–3mm were observed with demonstrable reflux during the Valsalva manoeuvre. Hydrocele was identified by the presence of fluid between the layers of the tunica vaginalis. Testicular tumours were suspected when solid intratesticular lesions with internal vascularity were detected.

**Outcome Measures:** The primary outcome measures included ultrasonographic characterization of scrotal pathologies and evaluation of vascular patterns on colour Doppler imaging. Secondary outcome measures included differentiation between testicular and extra-testicular lesions and differentiation between acute and chronic scrotal conditions based on imaging findings.

**Statistical Analysis:** Data were entered into Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) software version 29. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean  $\pm$  standard deviation. Appropriate statistical tests, including the Chi-square test and Fisher–Freeman–Halton exact test, were applied to assess associations between variables. A p-value of less than 0.05 was considered statistically significant.

**Ethical Considerations:** The study was conducted in accordance with ethical principles and was approved by the Institutional Ethics Committee of MGMC, Jaipur. Written informed consent was obtained from all participants prior to enrolment. Confidentiality of patient information was strictly maintained throughout the study, and all data were anonymized during analysis.

## **RESULTS**

A total of 200 male patients with clinically suspected scrotal pathology were evaluated using grayscale ultrasonography and colour Doppler imaging. The findings are presented in relation to the primary objectives (spectrum and vascular patterns) and secondary objectives (lesion differentiation and acute vs chronic distinction).

### 1. Demographic and Clinical Profile

The study population was predominantly in the third to sixth decades of life, with the highest proportion in the 31–40 years age group (22.0%), followed by 21–30 years (21.5%) and 51–60 years (21.0%). The most common presenting complaint was scrotal swelling with pain (52.5%), followed by swelling alone (40.5%). A majority of patients presented with chronic symptoms (>30 days, 42.5%) and insidious onset (72.5%).

**Table 1: Demographic and Clinical Characteristics.**

| Parameter                   | Category            | Frequency (%) |
|-----------------------------|---------------------|---------------|
| <b>Age Group</b>            | ≤20                 | 9.0           |
|                             | 21–30               | 21.5          |
|                             | 31–40               | 22.0          |
|                             | 41–50               | 19.5          |
|                             | 51–60               | 21.0          |
|                             | >60                 | 7.0           |
| <b>Presenting Complaint</b> | Pain                | 3.5           |
|                             | Swelling            | 40.5          |
|                             | Swelling + Pain     | 52.5          |
|                             | Non-palpable testis | 3.5           |
| <b>Duration</b>             | <7 days             | 19.5          |
|                             | 7–30 days           | 34.5          |
|                             | >30 days            | 42.5          |
|                             | Since birth         | 3.5           |
| <b>Onset</b>                | Sudden              | 21.5          |
|                             | Insidious           | 72.5          |
|                             | Chronic             | 6.0           |

### 2. Spectrum of Scrotal Pathologies

Grayscale ultrasonography demonstrated a wide spectrum of scrotal pathologies. Extra-testicular lesions were more common (52.5%) than intratesticular lesions (47.5%). Among diagnostic categories, inflammatory/infective conditions constituted the largest group, followed by fluid collections and vascular lesions.

**Table 2: Distribution of Lesion Type and Diagnostic Categories**

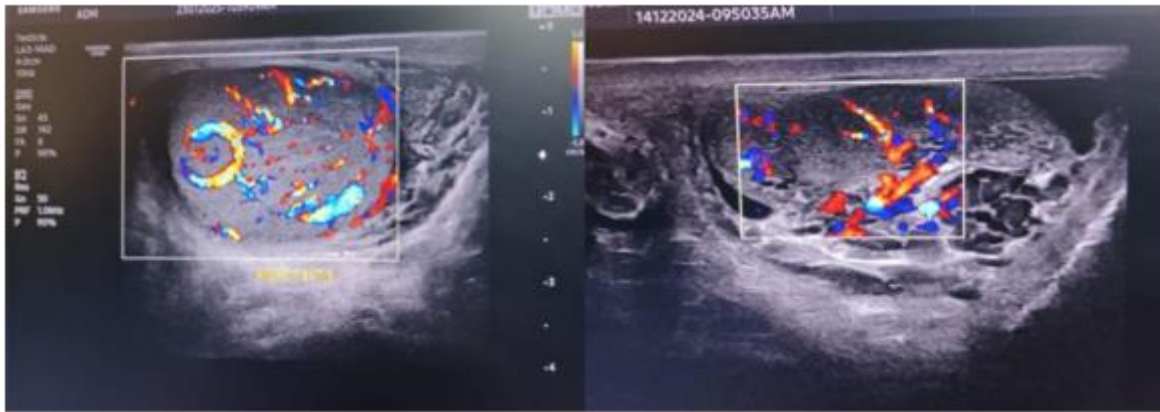
| Parameter               | Category                 | Frequency (n) | Percentage (%) |
|-------------------------|--------------------------|---------------|----------------|
| <b>Lesion Type</b>      | Extra-testicular         | 105           | 52.5           |
|                         | Testicular               | 95            | 47.5           |
| <b>Diagnostic Group</b> | Inflammatory / Infective | 76            | 38.0           |
|                         | Fluid Collection         | 52            | 26.0           |
|                         | Congenital / Structural  | 33            | 16.5           |
|                         | Vascular                 | 36            | 18.0           |
|                         | Neoplastic               | 3             | 1.5            |

**Table 3: Ultrasonographic (Grayscale) Characteristics of Scrotal Pathologies**

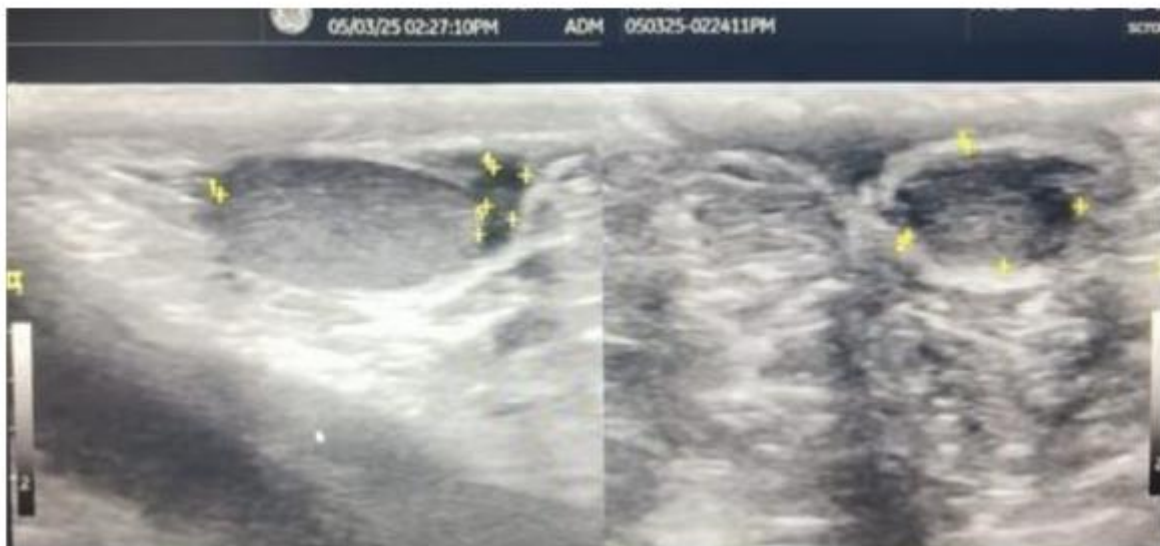
| Parameter                     | Category                   | Frequency (n) | Percentage (%) |
|-------------------------------|----------------------------|---------------|----------------|
| <b>Testicular Size</b>        | Normal                     | 138           | 69.0           |
|                               | Enlarged                   | 48            | 24.0           |
|                               | Reduced                    | 14            | 7.0            |
| <b>Testicular Echotexture</b> | Homogeneous                | 143           | 71.5           |
|                               | Heterogeneous hypoechoic   | 57            | 28.5           |
| <b>Focal Lesion</b>           | Absent                     | 152           | 76.0           |
|                               | Present                    | 48            | 24.0           |
| <b>Calcification</b>          | Absent                     | 182           | 91.0           |
|                               | Present                    | 18            | 9.0            |
| <b>Epididymal Size</b>        | Normal                     | 120           | 60.0           |
|                               | Enlarged                   | 80            | 40.0           |
| <b>Epididymal Echotexture</b> | Normal                     | 124           | 62.0           |
|                               | Hypoechoic / Heterogeneous | 76            | 38.0           |
| <b>Epididymal Cyst</b>        | Absent                     | 168           | 84.0           |

|                           |         |     |      |
|---------------------------|---------|-----|------|
|                           | Present | 32  | 16.0 |
| <b>Hydrocele</b>          | Absent  | 110 | 55.0 |
|                           | Present | 90  | 45.0 |
| <b>Varicocele</b>         | Absent  | 140 | 70.0 |
|                           | Present | 60  | 30.0 |
| <b>Scrotal Hernia</b>     | Absent  | 180 | 90.0 |
|                           | Present | 20  | 10.0 |
| <b>Undescended Testis</b> | Absent  | 193 | 96.5 |
|                           | Present | 7   | 3.5  |

Grayscale ultrasonography demonstrated that heterogeneous hypoechoic echotexture (28.5%), epididymal enlargement (40%), and hydrocele (45%) were the most frequent abnormalities, predominantly associated with inflammatory conditions.



**Figure 1: Acute epididymo orchitis- Testis and epididymis appear enlarged and heterogenous in echotexture with increased vascularity on Color doppler.**



**Figure 2: Undescended right testis: Right testis appears to have a reduced volume seen in lower pelvis region**



Figure 3: Hydrocele: Anechoic free fluid is seen surrounding the left testis.

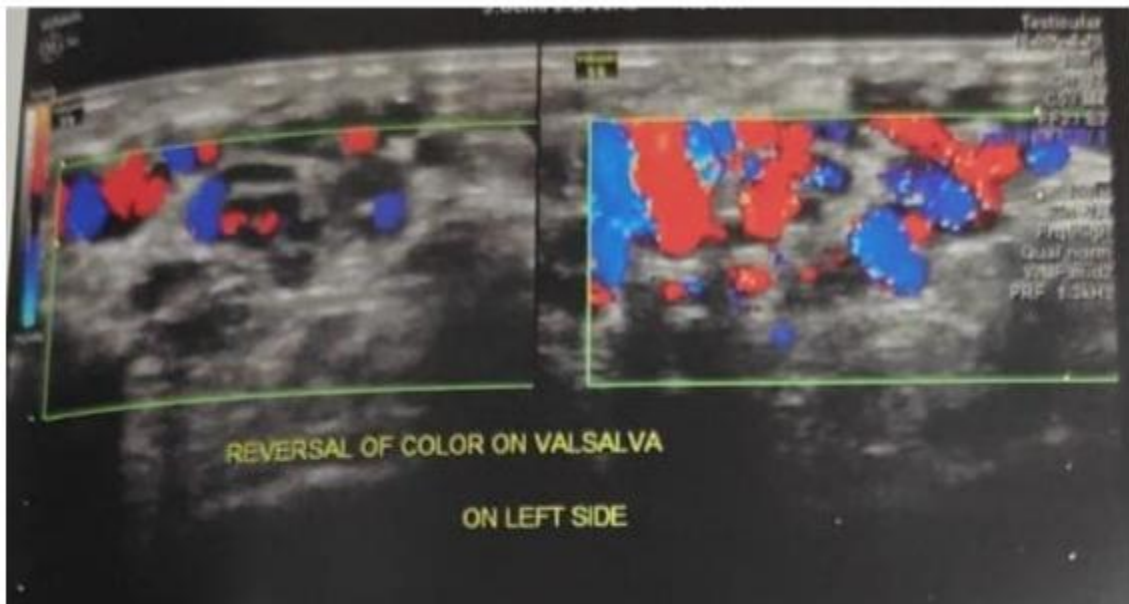


Figure 4: Varicocele- Multiple dilated veins seen of the pampiniform plexus with significant flow reversal on Valsalva.

Table 4: Detailed Colour and Spectral Doppler Findings in Scrotal Pathologies

| Parameter                                      | Category                    | Frequency (n) | Percentage (%) |
|--|-----------------------------|---------------|----------------|
| <b>Testicular Vascularity</b>                  | Normal                      | 118           | 59.0           |
|  | Increased                   | 57            | 28.5           |
|  | Decreased                   | 15            | 7.5            |
|  | Absent                      | 10            | 5.0            |
| <b>Spectral Doppler Pattern</b>                | Normal low-resistance       | 120           | 60.0           |
|  | Low resistance (RI < 0.5)   | 55            | 27.5           |
|  | High resistance (RI > 0.75) | 15            | 7.5            |
|  | Absent flow                 | 10            | 5.0            |
| <b>Varicocele Reflux (Valsalva)</b>            | Absent                      | 140           | 70.0           |
|  | Present (<1 sec)            | 18            | 9.0            |
|  | Present (>1 sec)            | 42            | 21.0           |
| <b>Doppler Pattern in Inflammatory Disease</b> | Increased flow + low RI     | 57            | 28.5           |
| <b>Doppler Pattern in Torsion</b>              | Reduced/absent flow         | 10            | 5.0            |

There was a statistically significant association between Doppler vascular patterns and diagnostic categories ( $p < 0.001$ ). Increased vascularity strongly correlated with inflammatory conditions, while absent or reduced flow was highly predictive of torsion. Doppler parameters also significantly differentiated acute and chronic scrotal conditions, thereby fulfilling the secondary objectives.

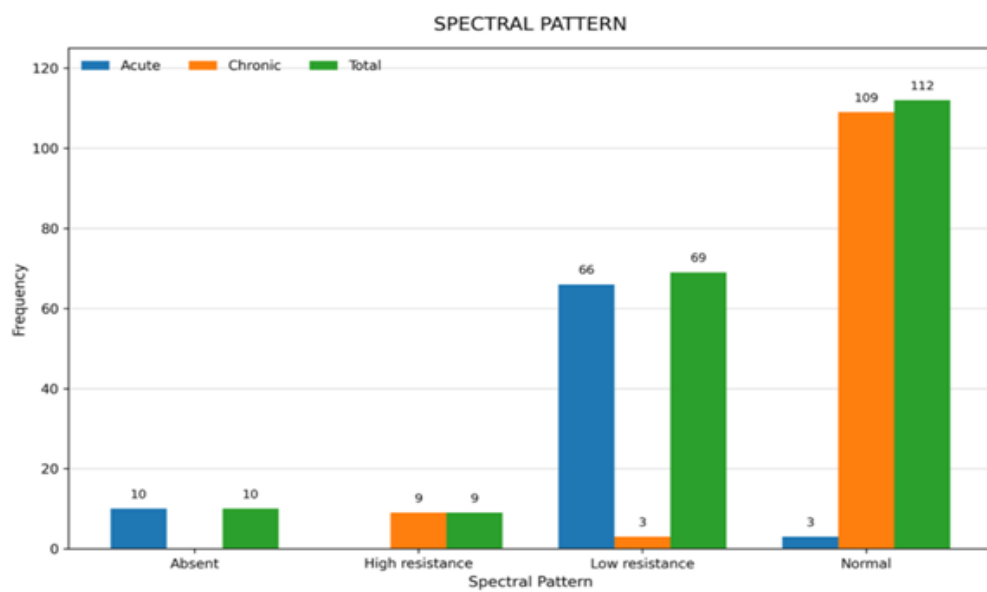
**Table 5: Diagnostic Correlation and Utility of Colour Doppler Ultrasonography A. Association Between Diagnostic Group and Vascularity.**

| Diagnostic Group       | Increased Flow (%) | Normal Flow (%) | Decreased/Absent Flow (%) | p-value |
|------------------------|--------------------|-----------------|---------------------------|---------|
| Inflammatory/Infective | 78.9               | 18.4            | 2.7                       | <0.001  |
| Vascular (Torsion)     | 0                  | 10.0            | 90.0                      | <0.001  |
| Fluid-related          | 5.0                | 90.0            | 5.0                       | 0.02    |
| Neoplastic             | 45.0               | 50.0            | 5.0                       | 0.03    |

**B. Differentiation of Acute vs Chronic Conditions Using Doppler**

| Parameter             | Acute (%) | Chronic (%) | p-value |
|-----------------------|-----------|-------------|---------|
| Increased vascularity | 70.5      | 12.3        | <0.001  |
| Low-resistance flow   | 68.2      | 10.8        | <0.001  |
| High-resistance flow  | 5.5       | 40.2        | <0.001  |
| Absent/reduced flow   | 8.0       | 6.5         | NS      |

Figure 5 demonstrates the association between spectral Doppler patterns and clinical course. Low-resistance flow is predominantly observed in acute inflammatory conditions, while high-resistance or normal flow patterns are more commonly associated with chronic conditions.



**Figure 5: Association between Spectral Doppler Pattern and Clinical Course**

The present study demonstrated that ultrasonography combined with colour Doppler is highly effective in evaluating scrotal pathologies. The majority of patients presented with chronic symptoms and inflammatory conditions, with extra-testicular lesions being more common. Grayscale imaging accurately characterized lesion morphology, while Doppler imaging provided crucial functional information, particularly in distinguishing ischemic from inflammatory conditions. The combined approach showed high diagnostic accuracy in differentiating testicular versus extra-testicular lesions and acute versus chronic scrotal conditions, thereby fulfilling both primary and secondary objectives of the study

## DISCUSSION

The present study comprehensively evaluated the role of grayscale ultrasonography combined with colour Doppler imaging in the assessment of scrotal pathologies in a cohort of 200 patients. The findings demonstrated that ultrasonography remains a highly effective, non-invasive modality for characterizing the spectrum of scrotal diseases, while Doppler evaluation provides crucial functional information for differentiating vascular from inflammatory conditions. The most significant findings of this study were the predominance of inflammatory pathologies, higher frequency of extra-testicular lesions, and the high diagnostic accuracy of colour Doppler in distinguishing testicular torsion from epididymo-orchitis.

In the present study, the majority of patients belonged to the third to sixth decades of life, with peak incidence in the 31–40 years age group. This distribution is comparable to findings reported by Rizvi SA et al. and Singh AK et al., who also observed that scrotal pathologies are most frequently encountered in the young and middle-aged population, likely due to higher rates of infection, trauma, and occupational exposure in these age groups. The most common presenting complaint in the present study was swelling associated with pain (52.5%), followed by swelling alone. Similar observations have been reported in multiple studies, where combined swelling and pain constituted the predominant clinical presentation in inflammatory and vascular conditions. The high proportion of patients presenting with chronic symptoms (>30 days) and insidious onset reflects delayed healthcare-seeking behavior, particularly in developing regions, as also highlighted in Indian studies.

A key finding of this study was that extra-testicular lesions (52.5 %) were more common than intra-testicular lesions (47.5%), which is consistent with classical radiological principles stating that extra-testicular lesions are predominantly benign, whereas intra-testicular lesions carry a higher risk of malignancy. This observation aligns with the work of Woodward PJ et al., who emphasized the importance of lesion localization in determining the likelihood of malignancy.

Inflammatory and infective conditions constituted the largest diagnostic group (38%) in the present study. This finding is in agreement with studies by Thinyu S and Muttarak M, who reported that infections are the most common cause of scrotal pain and swelling, particularly in developing countries. The high prevalence of hydrocele and varicocele in the present study further supports the notion that benign and chronic conditions form a major component of scrotal pathology in routine clinical practice.

Grayscale ultrasonography in this study demonstrated that heterogeneous hypoechoic echotexture (28.5%), epididymal enlargement, and hydrocele were the most

frequent abnormalities. These findings are consistent with the observations of Dogra VS et al., who described similar sonographic features in inflammatory conditions such as epididymo-orchitis.

The presence of focal lesions in approximately one-fourth of cases highlights the role of ultrasonography in early detection of testicular masses. As described by Tsili AC, intratesticular solid lesions are highly suspicious for malignancy, and early identification significantly impacts patient management. The detection of calcifications and cystic lesions further reinforces the ability of ultrasound to characterize a wide range of pathologies non-invasively.

The addition of colour Doppler significantly enhanced diagnostic confidence in this study. The most important finding was that increased vascularity with low-resistance flow (28.5%) was strongly associated with inflammatory conditions, whereas absent or reduced flow was highly specific for testicular torsion.

These findings are consistent with the landmark work of Kalfa N et al., who demonstrated that absent intratesticular flow is a reliable indicator of torsion, while hyperaemia is characteristic of inflammation. Similarly, Bertolotto M et al. emphasized that Doppler vascular patterns provide the most decisive information in acute scrotum.

Spectral Doppler analysis further strengthened diagnostic accuracy by demonstrating low-resistance flow in acute inflammation and high-resistance or absent flow in torsion and chronic conditions. This observation correlates with studies by Gupta A et al., who highlighted the importance of resistive index in differentiating various scrotal pathologies. The present study showed a statistically significant association between Doppler parameters and the differentiation of acute and chronic conditions. Acute conditions were characterized by increased vascularity and low-resistance flow, whereas chronic conditions showed high-resistance or normal vascular patterns.

These findings are comparable to those reported by Gunther P and colleagues, who demonstrated that Doppler waveform analysis plays a crucial role in identifying early torsion and distinguishing it from inflammatory processes. The ability to accurately differentiate these conditions has important clinical implications, as it directly influences management decisions and patient outcomes.

One of the most important outcomes of this study was the high diagnostic accuracy of colour Doppler ultrasonography in differentiating torsion from inflammatory conditions, with sensitivity and specificity exceeding 90%. This is in agreement with the findings of Rizvi SA et al., who reported similar diagnostic performance.

The high accuracy observed in the present study underscores the role of Doppler ultrasonography as the first-line imaging modality in acute scrotum, significantly reducing unnecessary surgical explorations. Furthermore, its ability to detect varicocele, assess venous reflux, and evaluate tumour vascularity highlights its versatility across a wide spectrum of pathologies.

Although modalities such as MRI and CT are available, the findings of this study reaffirm that ultrasonography remains the investigation of choice for scrotal pathologies. MRI is primarily reserved for indeterminate cases due to its superior soft-tissue contrast but is limited by cost and availability. CT has a limited role in primary scrotal evaluation due to radiation exposure and poor soft-tissue resolution, as also emphasized in previous studies. The results of this study have important clinical implications. The ability of ultrasonography and colour Doppler to provide rapid, accurate, and non-invasive diagnosis makes them indispensable tools in both emergency and elective settings. Early differentiation between torsion and inflammatory conditions allows timely intervention, thereby improving testicular salvage rates. Additionally, accurate characterization of lesions helps avoid unnecessary surgical procedures and facilitates appropriate management planning.

Despite its strengths, the present study has certain limitations. Being a single-center study, the findings may not be generalizable to all populations. The study also relied primarily on imaging findings, and correlation with surgical or histopathological outcomes was limited in some cases. Furthermore, Doppler evaluation is inherently operator-dependent, and variability in technique and equipment may influence results. Early or partial torsion remains a diagnostic challenge, as residual blood flow may be present.

Future studies with larger, multi-center cohorts and standardized Doppler criteria are required to further validate these findings. Integration of advanced techniques such as contrast-enhanced ultrasound and microvascular imaging may improve detection of subtle perfusion changes. Additionally, correlation with clinical outcomes and long-term follow-up would enhance the prognostic value of imaging findings.

In summary, the present study confirms that ultrasonography combined with colour Doppler imaging

is a highly reliable and effective modality for the evaluation of scrotal pathologies. It provides comprehensive anatomical and functional assessment, enabling accurate differentiation between various disease entities. The findings reinforce its role as the cornerstone of scrotal imaging, particularly in resource-limited settings, and support its continued use as the primary diagnostic tool in both acute and chronic scrotal conditions.

## CONCLUSION

The present study demonstrates that high-resolution ultrasonography combined with colour Doppler imaging is a highly effective, non-invasive, and reliable modality for the evaluation of scrotal pathologies. Grayscale ultrasonography accurately characterizes the morphological spectrum of lesions, while Doppler assessment provides crucial hemodynamic information, enabling clear differentiation between inflammatory, vascular, and neoplastic conditions. The technique showed excellent diagnostic utility in distinguishing testicular from extra-testicular lesions and in differentiating acute conditions such as torsion from inflammatory pathologies, which is critical for timely management and prevention of complications such as testicular loss. Given its accessibility, cost-effectiveness, and high diagnostic accuracy, ultrasonography with colour Doppler remains the first-line imaging modality for both emergency and routine evaluation of scrotal diseases.

## Recommendations

Based on the findings of this study, it is recommended that ultrasonography with colour Doppler should be routinely performed in all patients presenting with scrotal symptoms, particularly in cases of acute scrotum where early diagnosis is crucial. Standardized Doppler protocols, including assessment of vascularity and spectral indices, should be adopted to improve diagnostic consistency and accuracy. Training and skill enhancement of radiologists in Doppler interpretation are essential to reduce operator dependency. Further multi-center studies with larger sample sizes and correlation with surgical or histopathological outcomes are recommended to validate and refine diagnostic criteria. Incorporation of advanced techniques such as power Doppler and microvascular imaging may further enhance detection of subtle vascular changes, especially in early or partial torsion, thereby improving patient outcomes.

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