Journal of Health, Wellness and Community Research
ISSN: 3007, 0570

OPEN ACCESS

JHWCR

Type: Original Article
Published: 20 December 2025
Volume: III, **Issue**: XVIII
DOI: https://doi.org/10.61919/3f5jt524

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Received 10, 11, 25
Accepted 16, 12, 2025

Authors' Contributions
Concept: W M; Design: M U F, E N; Data Collection: N A, B F, A A; Analysis: M Y A, M A; Drafting: N A S, W M.

Declarations
No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Diagnostic Accuracy of Ultrasound in Differentiating Benign and Malignant Testicular Tumors Using Computed Tomography as the Gold Standard

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ABSTRACT

Background: *Testicular tumors represent a small but clinically significant proportion of male malignancies, predominantly affecting adolescents and young adults in whom early and accurate diagnosis is essential for optimal outcomes. Ultrasonography is widely used as the first-line imaging modality for evaluating testicular masses; however, variability in its specificity necessitates validation of its diagnostic performance against a reliable reference comparator in routine clinical practice.* ***Objective****: To evaluate the diagnostic accuracy of ultrasonography in differentiating benign and malignant testicular tumors using contrast-enhanced computed tomography as the reference comparator.* ***Methods****: This cross-sectional observational study was conducted at a tertiary diagnostic center in Islamabad over nine months and included 59 male patients aged 16–45 years with clinically suspected testicular masses. All participants underwent standardized gray-scale and color Doppler ultrasonography followed by contrast-enhanced computed tomography. Ultrasonographic findings were classified as benign or malignant based on predefined imaging criteria and compared with CT-based classification. Diagnostic performance metrics, including sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy, were calculated with 95% confidence intervals.* ***Results****: The mean age of participants was 31.27 ± 7.07 years. Ultrasonography classified 50.8% of lesions as malignant, while CT identified 55.9% as malignant. Compared with CT, ultrasonography demonstrated a sensitivity of 80.76% (95% CI: 67.5–91.1), specificity of 75.75% (95% CI: 61.1–87.0), positive predictive value of 72.41% (95% CI: 58.3–83.9), negative predictive value of 83.33% (95% CI: 70.4–92.1), and overall diagnostic accuracy of 77.96% (95% CI: 69.8–85.4).* ***Conclusion****: Ultrasonography showed high sensitivity and acceptable specificity for differentiating benign and malignant testicular tumors when compared with computed tomography, supporting its role as a reliable first-line imaging modality. Computed tomography remains valuable for confirmation and staging in indeterminate or suspicious cases.*

Keywords
Ultrasonography; Computed Tomography; Testicular Tumors; Diagnostic Accuracy; Scrotal Imaging

INTRODUCTION

Testicular tumors constitute a relatively uncommon but clinically important group of urogenital neoplasms, accounting for approximately 1% of male malignancies, with a disproportionate impact on adolescents and young-to-middle-aged men in whom timely diagnosis can preserve survival, fertility, and quality of life (1,2). International epidemiologic data demonstrate substantial geographic and temporal variation, with rising incidence trends reported across multiple regions over recent decades, reinforcing the need for efficient diagnostic pathways that can be implemented across diverse health systems (3,4). Although incidence is higher in several industrialized settings, the increasing detection of testicular lesions in developing countries—driven by heightened awareness and expanding access to imaging—has further amplified the clinical need for accurate, scalable, and resource-sensitive diagnostic strategies (5,6).

From a pathological standpoint, germ cell tumors comprise the vast majority of malignant intratesticular neoplasms, and their prognosis is strongly influenced by early detection and appropriate staging-directed management (7,8). Clinically, most patients present with painless swelling or a palpable lump, while pain and inflammatory symptoms may coexist and can obscure distinction between neoplastic and non-neoplastic conditions on physical examination alone (9,10). Because bedside assessment lacks sufficient discriminatory performance for lesion characterization, imaging plays a central role in the diagnostic workup and downstream treatment decisions, particularly when the immediate choice is between testis-sparing approaches, surveillance, and radical orchiectomy (11,12).

Ultrasonography is the first-line modality for evaluating scrotal and testicular abnormalities because it is non-invasive, radiation-free, widely available, and able to depict intratesticular lesions with high detection sensitivity using gray-scale imaging supplemented by color Doppler assessment of vascularity (13,14). Characteristic sonographic patterns—such as irregular margins, heterogeneous echotexture, and hypervascularity—may raise suspicion for malignancy, while well-circumscribed, homogeneous, and avascular lesions may favor benign etiologies; however, meaningful overlap persists with inflammatory, granulomatous, and other mimicking conditions, contributing to variability in specificity across practice environments and operators (15,16). This diagnostic gray zone is clinically consequential because overcalling malignancy can drive unnecessary orchiectomy, whereas undercalling malignancy risks delayed curative treatment and downstream metastatic burden.

Computed tomography is integral to testicular cancer evaluation primarily for staging, including assessment of retroperitoneal lymphadenopathy and distant spread, and it supports treatment planning once malignancy is suspected (17,18). Nonetheless, CT is not intrinsically optimized for definitive benign-versus-malignant discrimination of intratesticular masses compared with histopathology, and its routine use is constrained by ionizing radiation exposure, cost, and limited access in many resource-limited settings (19,20). In contexts where immediate histopathologic confirmation is not uniformly available for all suspected lesions, a pragmatic diagnostic accuracy framework comparing ultrasound classification against contrast-enhanced CT findings as a reference comparator can still provide clinically relevant evidence to guide triage, escalation, and staging pathways, particularly in regions where ultrasound is the predominant entry-point test.

Using a PICO framework, the present study focuses on men aged 16–45 years presenting with clinically suspected testicular masses (Population), undergoing gray-scale and color Doppler ultrasonography for lesion characterization (Index test), compared against contrast-enhanced computed tomography classification as the reference comparator where histopathology is not uniformly available (Comparator), to determine diagnostic accuracy metrics—sensitivity, specificity, predictive values, and overall accuracy—for differentiating benign from malignant testicular tumors (Outcomes). Accordingly, the objective was to evaluate the diagnostic accuracy of ultrasonography in differentiating benign and malignant testicular tumors using computed tomography as the reference comparator in a real-world diagnostic setting, with the hypothesis that ultrasound would demonstrate high sensitivity with acceptable specificity sufficient to justify its role as a first-line test while reserving CT for confirmation and comprehensive staging in indeterminate or suspicious cases.

MATERIAL AND METHODS

This cross-sectional observational diagnostic accuracy study was conducted at Health Next Diagnostic and Lab Centre, Islamabad, Pakistan, over a nine-month period. The study was designed to evaluate the performance of ultrasonography as an index test for differentiating benign and malignant testicular tumors using contrast-enhanced computed tomography as the reference comparator in a routine clinical diagnostic setting. The design was selected to reflect real-world practice, where ultrasound serves as the primary imaging modality and CT is selectively employed for further characterization and staging.

Male patients aged 16–45 years presenting with clinically suspected testicular masses were consecutively recruited during the study period. Eligibility criteria included unilateral or bilateral testicular swelling, palpable intratesticular lump, or sonographically suspected testicular lesion referred for diagnostic imaging. Patients with known contrast hypersensitivity, impaired renal function precluding contrast-enhanced CT, prior orchiectomy, or incomplete imaging evaluation were excluded to ensure uniform assessment. Consecutive sampling was employed to minimize selection bias and reflect the clinical spectrum of disease. Written informed consent was obtained from all participants prior to enrollment.

All participants underwent standardized scrotal ultrasonography followed by contrast-enhanced computed tomography. Ultrasound examinations were performed using a Toshiba Xario system equipped with a high-frequency linear transducer (6–12 MHz). Patients were examined in the supine position, and both testes were systematically evaluated in longitudinal and transverse planes. Sonographic variables included lesion size, echogenicity, homogeneity, margin characteristics, presence of calcification, associated hydrocele or pyocele, and intralesional vascularity on color Doppler imaging. For diagnostic classification, lesions demonstrating irregular margins, heterogeneous echotexture, and increased internal vascularity were categorized as malignant, whereas well-defined, homogeneous, and avascular lesions were classified as benign. In cases with multiple lesions within a single testis, the most suspicious lesion was selected for analysis to maintain consistency.

Contrast-enhanced computed tomography was performed using a 64-slice multidetector CT scanner following intravenous administration of iodinated contrast. Axial images with multiplanar reconstructions were reviewed. CT assessment focused on testicular lesion characteristics, evidence of local extension, bilateral involvement, regional lymphadenopathy, and distant metastatic features. For the purposes of this study, CT-based classification of lesions as benign or malignant was determined by radiologic criteria consistent with neoplastic behavior, including invasive features and metastatic spread, and was used as the reference comparator.

Ultrasound and CT images were independently interpreted by two consultant radiologists with more than five years of experience in diagnostic imaging. Radiologists interpreting ultrasound images were blinded to CT findings, and CT interpreters were blinded to ultrasound results to reduce observer bias. Discrepancies were resolved by consensus review. Data were recorded on a structured proforma at the time of imaging to ensure data integrity and reproducibility.

The primary outcome was the diagnostic performance of ultrasonography in differentiating benign and malignant testicular tumors relative to CT classification. Secondary variables included the frequency of specific imaging features such as calcification, hydrocele, bilateral involvement, and suspected metastatic findings. Sample size was determined a priori using a diagnostic accuracy formula for sensitivity estimation, based on previously reported ultrasound sensitivity, anticipated disease prevalence, 95% confidence level, and acceptable precision, yielding a required sample of 59 participants.

Statistical analysis was performed using IBM SPSS Statistics version 25. Continuous variables were summarized as mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Diagnostic accuracy measures, including sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy, were calculated with 95% confidence intervals. A two-by-two contingency table was constructed to derive these estimates. Missing data were assessed at the point of entry and were not present in the final dataset. All analyses were conducted using two-tailed statistical testing where applicable.

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and approval was obtained from the institutional ethics review committee prior to commencement (21). Confidentiality of participant data was maintained throughout the study, and all procedures followed standardized imaging and reporting protocols to ensure reproducibility by other investigators.

RESULTS

A total of 59 male patients with clinically suspected testicular masses were included in the final analysis. The mean age of participants was 31.27 ± 7.07 years (range: 20–45 years), and the mean body weight was 72.74 ± 8.22 kg. Baseline demographic characteristics are summarized in Table 1. All enrolled participants completed both ultrasonography and contrast-enhanced computed tomography examinations and were included in the diagnostic accuracy analysis, with no missing data. Clinically, testicular swelling was present in all patients (100%). Pain was reported in 61.0% of cases, while 39.0% presented with a painless lump. Testicular enlargement was observed in 88.1% of patients, and systemic symptoms were documented in 45.8%. On physical examination, lesion consistency was categorized as soft in 30.5%, firm in 33.9%, and hard in 35.6% of cases, while surface characteristics were evenly distributed between smooth (50.8%) and irregular (49.2%) contours. The distribution of presenting clinical features is detailed in Table 2. Ultrasonographic evaluation revealed imaging features suggestive of advanced or aggressive disease patterns in a substantial proportion of cases. Increased intralesional vascularity on color Doppler imaging was identified in 59.3% of lesions, while irregular lesion margins were observed in 59.3%. Calcifications were detected in 59.3% of cases, hydrocele in 45.8%, pyocele in 8.5%, and coexistent orchitis in 28.8%. Sonographic features interpreted as suspicious for metastatic or extratesticular extension were reported in 35.6% of patients, and bilateral testicular involvement was documented in 79.7%. Based on the composite sonographic assessment, 29 lesions (49.2%) were classified as benign and 30 lesions (50.8%) as malignant (Table 3).

Table 1. Demographic Characteristics of Study Participants (n = 59)

Variable	Mean ± SD	Range
Age (years)	31.27 ± 7.07	20–45
Weight (kg)	72.74 ± 8.22	58–89

Table 2. Clinical Presentation of Patients With Testicular Masses (n = 59)

Clinical Feature	Present n (%)	Absent n (%)
Testicular swelling	59 (100.0)	0 (0.0)
Pain	36 (61.0)	23 (39.0)
Testicular enlargement	52 (88.1)	7 (11.9)
Systemic symptoms	27 (45.8)	32 (54.2)
Painless lump	23 (39.0)	36 (61.0)

Table 3. Ultrasonographic Characteristics of Testicular Lesions (n = 59)

Ultrasound Feature	Present n (%)	Absent n (%)
Suspicious metastatic features	21 (35.6)	38 (64.4)
Bilateral involvement	47 (79.7)	12 (20.3)
Calcification	35 (59.3)	24 (40.7)
Hydrocele	27 (45.8)	32 (54.2)
Pyocele	5 (8.5)	54 (91.5)
Orchitis	17 (28.8)	42 (71.2)
Irregular margins	35 (59.3)	24 (40.7)
Final US classification (malignant)	30 (50.8)	—
Final US classification (benign)	29 (49.2)	—

Table 4. Computed Tomography Findings of Testicular Lesions (n = 59)

CT Feature	Present n (%)	Absent n (%)
Metastatic disease	36 (61.0)	23 (39.0)
Bilateral involvement	33 (55.9)	26 (44.1)
Calcification	35 (59.3)	24 (40.7)
Hydrocele	33 (55.9)	26 (44.1)
Pyocele	7 (11.9)	52 (88.1)
Final CT classification (malignant)	33 (55.9)	—
Final CT classification (benign)	26 (44.1)	—

Table 5. Diagnostic Performance of Ultrasonography Compared With Computed Tomography

Diagnostic Parameter	Estimate (%)	95% Confidence Interval
Sensitivity	80.76	67.5–91.1
Specificity	75.75	61.1–87.0
Positive Predictive Value	72.41	58.3–83.9
Negative Predictive Value	83.33	70.4–92.1
Overall Accuracy	77.96	69.8–85.4

Computed tomography identified imaging features consistent with malignant disease in a higher proportion of cases. CT demonstrated suspected metastatic disease in 61.0% of patients, bilateral involvement in 55.9%, calcification in 59.3%, hydrocele in 55.9%, and pyocele in 11.9%. Based on CT classification used as the reference comparator, 33 lesions (55.9%) were categorized as malignant and 26 lesions (44.1%) as benign. These findings are summarized in Table 4. Diagnostic accuracy analysis demonstrated that ultrasonography correctly identified 21 of 26 CT-classified malignant lesions and correctly excluded malignancy in 25 of 33 CT-classified benign lesions. The resulting sensitivity of ultrasonography was 80.76% (95% CI: 67.5–91.1), and specificity was 75.75% (95% CI: 61.1–87.0). The positive predictive value was 72.41% (95% CI: 58.3–83.9), while the negative predictive value was 83.33% (95% CI: 70.4–92.1). Overall diagnostic accuracy was calculated as 77.96% (95% CI: 69.8–85.4). These performance estimates are presented in Table 5. Collectively, these results indicate that ultrasonography demonstrated high sensitivity and moderate-to-good specificity for differentiating benign and malignant testicular tumors when compared with CT-based classification, supporting its role as a robust first-line diagnostic modality in the evaluation of suspected testicular neoplasms.

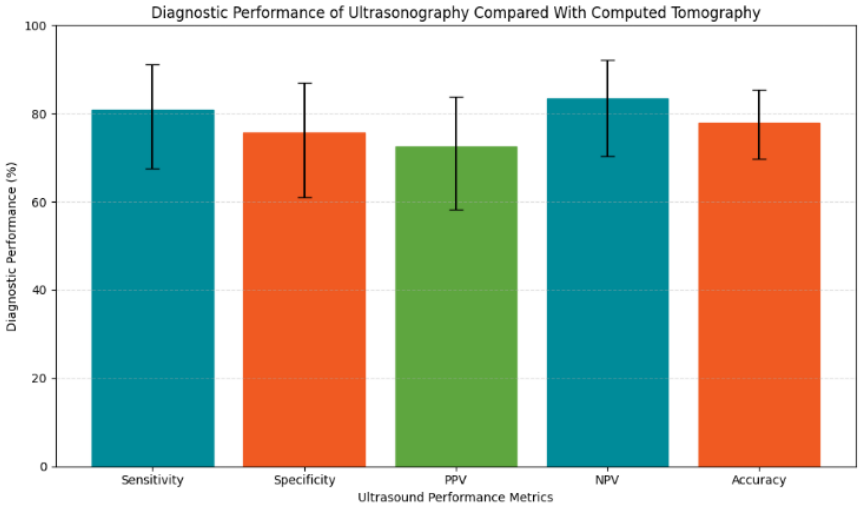

Figure 1 Figure 1. Diagnostic Performance Profile of Ultrasonography Relative to Computed Tomography

The figure illustrates a comparative performance profile of ultrasonography across key diagnostic accuracy parameters when benchmarked against computed tomography. Sensitivity reached 80.76% (95% CI: 67.5–91.1), indicating strong ability of ultrasound to correctly identify CT-classified malignant testicular lesions, while specificity was 75.75% (95% CI: 61.1–87.0), reflecting a moderate capacity to correctly exclude benign disease. The negative predictive value was highest at 83.33% (95% CI: 70.4–92.1), suggesting that lesions characterized as benign on ultrasound were unlikely to be malignant on CT, a clinically important feature for reducing unnecessary invasive interventions. In contrast, the positive predictive value was comparatively lower at 72.41% (95% CI: 58.3–83.9), highlighting residual diagnostic uncertainty in ultrasound-positive cases that may warrant further cross-sectional imaging or histopathologic confirmation. The overall diagnostic accuracy of 77.96% (95% CI: 69.8–85.4) demonstrates a balanced performance across metrics, with overlapping confidence intervals indicating consistent diagnostic behavior rather than metric-specific instability. Collectively, the gradient pattern across these parameters underscores the role of ultrasonography as a reliable rule-out and first-line triage modality, while reinforcing the complementary value of computed tomography in confirming and staging suspicious testicular tumors.

DISCUSSION

The present study evaluated the diagnostic performance of ultrasonography in differentiating benign and malignant testicular tumors using contrast-enhanced computed tomography as a reference comparator in a real-world diagnostic setting. The findings demonstrate that ultrasonography achieved a sensitivity of 80.76% and a specificity of 75.75%, with an overall diagnostic accuracy of 77.96%. These results indicate that ultrasound performs well as an initial discriminative tool, particularly in identifying malignant lesions, and provide empirical support for its continued role as the first-line imaging modality in patients presenting with suspected testicular masses.

The observed sensitivity aligns with prior literature reporting high detection capability of ultrasonography for intratesticular malignancies, often exceeding 80% in both conventional and Doppler-based assessments (22,23). The relatively high negative predictive value observed in this study (83.33%) is of particular clinical importance, as it suggests that lesions categorized as benign on ultrasound are unlikely to represent malignant disease on CT, thereby supporting conservative management or surveillance strategies in selected patients. This finding is consistent with earlier reports indicating that ultrasound is especially effective as a rule-out test in the diagnostic pathway of scrotal and testicular pathology (24,25). Conversely, the moderate positive predictive value reflects persistent overlap in imaging features between malignant tumors and certain benign or inflammatory conditions, such as orchitis or granulomatous disease, which has been widely recognized as a limitation of sonographic characterization alone (26).

When compared with previous diagnostic accuracy studies using histopathology as the reference standard, the specificity observed in the present study is comparable to, or slightly higher than, values reported in several regional and international cohorts, where specificity has ranged between 60% and 75% (27–29). Variability in specificity across studies may be attributed to differences in operator expertise, imaging equipment, lesion spectrum, and reference standards used. The use of CT as a reference comparator in this study reflects pragmatic clinical practice in settings where histopathologic confirmation is not immediately available for all patients and where CT plays a central role in downstream staging and management decisions. While CT is not optimized for definitive benign-versus-malignant discrimination of intratesticular lesions, its ability to demonstrate invasive features, bilateral involvement, and metastatic spread provides clinically meaningful confirmation in equivocal cases (30,31).

The high frequency of sonographic features such as irregular margins, increased vascularity, and calcification among malignant lesions observed in this cohort is consistent with established pathophysiologic mechanisms of tumor angiogenesis and tissue heterogeneity in germ cell tumors (32).

Increased Doppler flow reflects neovascularization, a hallmark of malignant transformation, whereas irregular contours and heterogeneous echotexture correspond to infiltrative growth patterns and necrosis. However, inflammatory conditions may also demonstrate hyperemia, which partially explains the reduced specificity and underscores the importance of integrating imaging findings with clinical context and, where necessary, complementary imaging or histopathologic evaluation (33).

This study has several strengths, including its prospective consecutive sampling approach, standardized imaging protocols, blinded interpretation by experienced radiologists, and complete dataset without missing values, all of which enhance internal validity and reproducibility. Nonetheless, certain limitations merit consideration. The single-center design and modest sample size may limit generalizability to broader populations with different disease prevalence or healthcare resources. The absence of histopathologic confirmation as a universal reference standard restricts inference regarding true diagnostic accuracy for benign versus malignant pathology, as CT-based classification may misclassify certain lesion subtypes. Additionally, interobserver agreement statistics were not quantified, which may have provided further insight into reproducibility across readers.

Future research should focus on multicenter studies with larger cohorts and systematic incorporation of histopathology to validate and refine sonographic criteria for malignancy. The integration of advanced techniques such as contrast-enhanced ultrasound and elastography may further improve specificity and reduce diagnostic ambiguity. From a clinical perspective, the present findings support a tiered diagnostic approach in which ultrasonography serves as the primary screening and triage tool, with CT reserved for confirmation, staging, and assessment of suspected metastatic disease, thereby optimizing diagnostic efficiency while minimizing unnecessary radiation exposure and healthcare costs.

CONCLUSION

In conclusion, ultrasonography demonstrated a high level of diagnostic performance in differentiating benign from malignant testicular tumors, achieving strong sensitivity and acceptable specificity when compared with computed tomography as a reference comparator. These findings support the role of ultrasound as a reliable, non-invasive, and readily accessible first-line imaging modality for the evaluation of suspected testicular masses, particularly in young and middle-aged men where early detection is critical for favorable outcomes. The high negative predictive value underscores its clinical utility in safely excluding malignancy and guiding conservative management when appropriate, while computed tomography remains valuable for confirmation and staging in indeterminate or suspicious cases. Collectively, this ultrasound-first, CT-selective diagnostic strategy has important implications for improving diagnostic efficiency, reducing unnecessary radiation exposure, and optimizing patient-centered care in both resource-rich and resource-limited healthcare settings.

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