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DIAGNOSTIC ACCURACY OF ULTRASONOGRAPHY IN DIAGNOSING TESTICULAR TUMORS USING MRI AS THE GOLD STANDARD

Jamal Tauqir[1], Asya Tauqir[2], Hamza Javed[3], Faiza Akram[*4]

[1,3] Resident Radiologist, Ayub Teaching Hospital-Abbottabad.
[2]Assistant Professor Community Medicine, Women Medical College- Abbottabad
*[*4]Professor Radiology, Ayub Teaching Hospital-Abbottabad*

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Corresponding Author: *
Faiza Akram

Abstract

Introduction

Testicular tumors require accurate and timely diagnosis to guide appropriate clinical management. Ultrasonography (US) is widely used as the first-line modality due to its accessibility and cost-effectiveness. This study aimed to determine the diagnostic accuracy of US in detecting testicular tumors using MRI as the reference standard.

Methodology

This cross-sectional validation study included 128 male patients aged ≥18 years. Patients presenting with scrotal symptoms between September 2024 and December 2025 were included using consecutive sampling technique. All patients underwent US followed by MRI on a 1.5T scanner at radiology department of Ayub Teaching Hospital- Abbottabad. MRI findings served as the diagnostic standard. validity parameters were calculated from a 2x2 contingency between US findings taking MRI findings as reference standard. Associations between imaging and clinical features and tumor diagnosis were assessed at a 5% significance level.

Results

MRI confirmed a testicular tumor in 87 (67.9%) patients. US correctly identified 73 of these cases. The diagnostic performance of US was: sensitivity 83.91%, specificity 75.61%, PPV 87.95%, NPV 68.89%, and overall diagnostic accuracy 81.25%. Sonographic features significantly associated with tumor diagnosis included hypoechogenicity, irregular margins, and heterogeneous echotexture ($p < 0.001$). MRI features significantly associated with tumors included hypo-/isointensity on T1-weighted images, hyperintensity on T2-weighted images, restricted diffusion, and contrast enhancement ($p < 0.001$). Clinical variables such as age, lesion size, and symptom duration were not significantly associated with presence of tumor.

Conclusions

Ultrasonography demonstrates moderate to high sensitivity and diagnostic accuracy. Testicular sonography is an appropriate first-line investigation for suspected testicular tumors. However, MRI is indispensable for lesions with equivocal or suspicious sonographic features, as it improves lesion characterization and reduces misclassification.

ITRODUCTION

Testicular tumors, about 1% of male cancers, pose a significant health concern due to rising incidence (1,2). Accurate and timely diagnosis is crucial for effective treatment and management. Among the various diagnostic modalities, ultrasonography (US) and MRI are the most prominent (3,4). US is typically the first-line imaging technique for evaluating testicular abnormalities due to its accessibility, cost-effectiveness, and real-time imaging capabilities. It provides essential information about the size, location, and internal characteristics of the lesion, aiding in the differentiation between benign and malignant tumors. High-frequency transducers used in US can detect even small lesions, making it an invaluable tool in initial assessments (5). Specific features on US, such as hypoechoic areas, irregular margins, and internal vascularity assessed by Doppler imaging, are indicative of malignancy (6).

Despite its advantages, ultrasonography has limitations, particularly in distinguishing certain benign from malignant lesions and in the precise characterization of complex testicular tumors. This is where advanced imaging capabilities of MRI come into play. MRI offers detailed tissue characterization through various sequences and parameters, such as T1-weighted imaging, T2-weighted imaging, diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC) values and post-contrast imaging. MRI has the ability to differentiate between tumor types and stages, providing crucial information for planning treatment strategies (7,8).

In clinical practice, the integration of US and MRI allows for a comprehensive evaluation of testicular tumors. Initial screening with US followed by confirmatory and detailed assessment with MRI ensures high diagnostic accuracy, guiding appropriate clinical management (9). This combined approach helps in not only diagnosing the presence of a tumor but also in understanding its nature, extent, and possible histological type, which are pivotal for determining the optimal therapeutic approach (10). The synergy of both imaging modalities enhances diagnostic accuracy, ultimately improving patient outcomes in the management of testicular tumors (11,12).

However, there is paucity of information related to diagnostic role of US for testicular tumors in population of Hazara region of KPK. Therefore, this study aims to assess the diagnostic accuracy of US in this population. Findings of the study may improve clinical decision-making in the management of testicular tumors. The findings are expected to provide guiding US features for when MRI should be utilized in the diagnostic workup. This will streamline the decision-making process, reduce unnecessary imaging, and optimize patient care and resource allocation.

MATERIAL AND METHODS:

The study was designed as a cross-sectional validation study conducted at the Department of Diagnostic Radiology at Ayub Teaching Hospital, Abbottabad. The research aimed to assess the diagnostic accuracy of US in diagnosing testicular tumors, using MRI as the gold standard. Ethical approval was obtained prior to commencement, and a total sample size of 128 participants was determined based on the anticipated frequency of testicular tumors (48.55%) and the sensitivity (88.8%) and specificity (78.1%) of US, with an absolute precision of 10% and a 95% confidence interval (13). A non-probability, consecutive sampling technique was employed to recruit eligible participants.

Male patients aged 18 years and above, presenting with symptoms such as painless swelling, heaviness or aching in the scrotum, and sudden fluid accumulation, were included in the study. Patients with known undescended testes or those who had undergone orchiectomy were excluded. Informed consent was obtained from all participants after explaining the aims, procedures, risks, and benefits of the study. Confidentiality of participants' data was strictly maintained, and they were informed about their right to withdraw from the study at any time without affecting their treatment.

Data collection was carried out over a 16 months period (September 2024 till December 2025). Ethics approval was obtained from the medical ethics committee of Ayub Medical Teaching

Institution (RC-EA-2024/160). Demographic information, including age, gender, duration of symptoms, findings of US and MRI, were recorded on a proforma. Medical records were also reviewed to gather relevant clinical history, including any comorbidities such as diabetes and hypertension, as well as previous imaging studies. The diagnostic process involved US as the initial imaging modality. If clinically indicated, it was followed by MRI for confirmation and further characterization of the testicular lesions. All MRI scans were performed using a standardized protocol on a 1.5T MRI system, which included T1-weighted, T2-weighted, FLAIR, ADC, DWI, T2*-weighted sequences, and post-contrast imaging. Each MRI was interpreted by a consultant radiologist with at least five years of post-fellowship experience.

Statistical analysis was performed using SPSS version 27.0. The normality of continuous variables, such as age and duration of symptoms, was assessed using the Shapiro-Wilk test. Descriptive statistics, including mean ± standard deviation (SD) and median (IQR), were used. Categorical variables, such as gender, residence, profession, education, and diagnosis, were expressed as frequencies and percentages. The diagnostic validity parameters of US in detecting testicular tumors were calculated from a 2x2 contingency table between US findings with MRI findings as references standard. Stratification was applied to address potential effect modifiers, such as age, gender, and duration of symptoms. Post-stratification, the chi-square test or Fisher's exact test was used at a 5% significance level to determine any significant associations between clinical factors and MRI findings.

RESULTS

Table 1: Demographic and Clinical Characteristics of Participants

Characteristic	Mean ± SD	Median (IQR)
Age (Years)	42.55 ± 15.04	41.50 (29 - 56)
Durations of symptoms (Months)	6.78 ± 3.35	7.0 (4.0 – 10.0)
Size of lesion (cm)	2.99 ± 1.05	3.10 (2.04 – 3.82)
Socio-demographic Characteristics		Frequency (Percentage)
Residence	Rural	26 (20.3%)
	Urban	102 (79.7%)
Profession	Laborer	46 (35.9%)
	Other	39 (30.5%)
	Professional	43 (33.6%)
Education	No formal education/ Middle school	37 (28.9%)
	High school	33 (25.8%)
	Bachelors	33 (25.8%)
	Master's	25 (19.5%)
Marital Status	Married	63 (49.2%)
	Single	65 (50.8%)
Diabetes	Non-diabetic	112 (87.5%)
	Diabetic	16 (12.5%)
Hypertension	Non-hypertensive	109 (85.2%)
	Hypertensive	19 (14.8%)

Table 1 summarizes the demographic and clinical characteristics of the participants. The sample included majority of urban (79.7%) residents, with a majority of participants being laborers (35.9%). The educational background varied, with 28.9% having no formal education or middle school education, while 19.5% held a Master's degree. The age range of participants was between 18 and 80 years, with a mean age of 42.55 years. The duration of symptoms ranged from 1 to 12 months, with a median duration of 7 months. The size of the lesions varied between 1.5 cm and 5.0 cm, with a mean size of 2.99 cm. These socio-demographics shows a population of lower socio-economic background with low literacy and poor health consciousness or inability to seek timely medical help.

Table 2: Ultrasonographic features associated with testicular tumors

Ultrasound Features		**Diagnosed as malignant tumor by MRI**		**Total**	**P value**
		Yes	No		
Hypoechoic Lesion	Yes	63	20	83	0.009
	No	24	21	45	
Irregular Margins	Yes	64	16	80	<0.001
	No	23	25	48	
Internal Vascularity	Yes	64	25	89	0.149
	No	23	16	39	
Echotexture	Heterogeneous	69	16	85	<0.001
	Homogeneous	18	25	43	
Presence of Calcifications	Yes	11	4	15	0.636
	No	76	37	113	

Table 2 presents the US findings of MRI-confirmed testicular tumors. Hypoechoic appearance, irregular margins and heterogenous echotexture were all significantly associated with a testicular tumor diagnosis by MRI ($p = 0.009$, $p < 0.001$ and $p < 0.001$ respectively). However, the presence of internal vascularity and calcifications did not show a significant relationship with a diagnosis of testicular cancer ($p = 0.149$ and $p = 0.636$, respectively). These results suggest that US is a valuable tool in assessment of testicular lesions, particularly echogenicity, echotexture and characteristics of lesion margins.

Table 3: Characteristic Features of Testicular Tumors on MRI

MRI Features		**Diagnosis of Tumor by MRI**		**Total**	**P value**
		Yes	No		
Hypo/ Iso-intense Lesion on T1WI	Yes	82	6	88	<0.001
	No	5	35	40	
Hyperintense Lesion on T2WI	Yes	50	8	58	<0.001
	No	37	33	70	
Restricted Diffusion	Yes	71	27	98	<0.001
	No	16	14	30	
Contrast Enhancement	Yes	77	2	79	<0.001
	No	10	39	49	
Intra-tumoral Septa	Yes	50	26	76	0.523
	No	37	15	52	
Cystic Changes	Yes	20	12	32	0.444
	No	67	29	96	
Peri-tumoral Infiltration	Yes	27	7	34	0.095

	No	60	34	94	

As shown in table 3, the characteristic features of testicular tumors on MRI, including hypo-/iso-intensity on T1-weighted images, hyperintensity on T2-weighted images, restricted diffusion, and contrast enhancement, showed statistically significant correlations with MRI-confirmed tumors ($p<0.001$ for all the mentioned features). However, features such as intra-tumoral septa ($p = 0.523$), cystic changes ($p = 0.444$), and peri-tumoral infiltration ($p = 0.095$) did not show significant relationships with tumor presence. This could be due either to the lower occurrence of septation or cystic changes in testicular tumors or lower frequency of patients to present with these features at the time of the diagnostic workup.

Table 4: Comparison of clinical Parameters of diagnosed cases of Testicular Tumor vs non-tumoral pathology.

Clinical parameters	Diagnosed by MRI	N	Mean	SD	P value
Age (years)	Yes	87	42.02	15.289	0.562
	No	41	43.68	14.629	
Size of Lesion (cm)	Yes	87	3.0991	1.05317	0.08
	No	41	2.7505	1.01554	
Duration of Symptoms (months)	Yes	87	7.14	3.271	0.079
	No	41	6.02	3.431	

Table 4 compares clinical parameters of patients with and without the diagnosis of testicular tumors by MRI. The analysis shows no significant difference in age ($p = 0.562$), symptom duration ($p = 0.08$), or lesion size ($p = 0.079$) between the patients with and without testicular tumors. This implies that clinical characteristics alone are insufficient for the diagnosis of a testicular tumor.

Table 5: 2x2 contingency table Comparing the Testicular Tumor Diagnosis by Ultrasound and MRI

		Diagnosis of Testicular Tumor on MRI		Total	P value
		Yes	No		
Diagnosis of Testicular Tumor on Ultrasound	Yes	73	10	83	<0.001
	No	14	31	45	
Total		87	41	128	

Table 5 shows that out of 128 total participants, 73 patients with a testicular tumor were identified correctly by ultrasound, yielding a True Positive (TP) of 73. On the other hand, 14 tumor cases were missed by ultrasound. The association between ultrasound findings and MRI diagnoses is statistically significant with a p-value of <0.001. The validity metrics as calculated from this 2x2 contingency table showed a sensitivity of 83.91%, specificity of 75.61%, positive predictive value (PPV) of 87.95%, negative predictive value (NPV) of 68.89%, and a diagnostic accuracy of 81.25%, for correct diagnoses of testicular tumor made by ultrasound.

DISCUSSION

The findings of this study endorse the continued value of US as the first-line imaging modality for the evaluation of testicular tumors, while simultaneously affirming the superiority of MRI as the reference standard for definitive diagnosis. In our patients, US demonstrated a sensitivity and specificity that is consistent with previously reported ranges, thereby validating its role as a practical, accessible, and cost-effective diagnostic tool. However, the modest false-positive and false-negative rates observed highlight the inherent limitations of US in the differentiation between benign and malignant lesions.

US has long been considered the cornerstone of scrotal imaging because of its real-time capability, lack of ionizing radiation, and wide availability (12,14). The results indicated that sonographic features such as hypoechoic texture, irregular margins, and heterogeneous echotexture showed significant concordance with diagnosis of testicular neoplasm. As per published literature, doppler and grayscale sonography can effectively identify hypoechoic intratesticular lesions, irregular margins, and internal vascularity—features highly suggestive of malignancy (14,15). Our results align with Naz et al., who reported a diagnostic accuracy of 77% for Color Doppler US in testicular tumors (15), and with Belfield and Findlay-Line, who reaffirmed that although US provides reliable initial detection, morphological characterization remains challenging (14). Also, US may not reliably differentiate benign from malignant lesions—findings corroborated by recent studies emphasizing the overlapping morphological characteristics of testicular tumors on ultrasound (3).

Despite these strengths, US is operator-dependent and sometimes inconclusive, especially in the assessment of complex or small lesions. MRI, particularly multiparametric MRI (mpMRI), provides superior soft-tissue contrast, advanced tissue characterization, and functional insights that go beyond the morphological details visible on US (12). Tsili et al. emphasized that MRI is strongly recommended in equivocal US cases, aiding in tumor localization, preoperative staging, and discrimination between germ-cell and non-germ-cell neoplasms (12). Our findings resonate with this evidence, demonstrating that MRI was indispensable in confirming diagnoses and preventing misclassification.

Emerging adjuncts in US, such as contrast-enhanced ultrasound (CEUS) and sonoelastography, are beginning to bridge the gap between US and MRI. Gupta et al. reported that while conventional US is highly sensitive in detecting intratesticular masses, characterization of tumor type remains challenging; CEUS can provide additional specificity, especially in differentiating germ cell tumors from other neoplasms (16). Similarly, Xue et al. demonstrated that CEUS significantly improved accuracy over conventional US in discerning germ cell from non-germ cell tumors in older patients, advocating its complementary role in clinical decision-making (7). A recent meta-analysis by Yu et al. demonstrated that CEUS improves diagnostic accuracy, with pooled sensitivity and specificity of 92% and 91%, respectively (17). Similarly, Lai et al. reported that sonoelastography achieved a pooled sensitivity of 86% in distinguishing benign from malignant tumors (18). These modalities, though not yet universally available, hold promise for enhancing non-invasive testicular imaging.

The clinical implications of accurate imaging are profound. Over-diagnosis of benign tumors as malignant can result in unnecessary radical orchiectomy, compromising fertility and quality of life. Song et al. highlighted that up to 24% of patients undergoing orchiectomy had benign histology, a figure much higher than the previously presumed 10% (19). Likewise, studies on Leydig cell tumors (LCTs) have shown that these benign lesions often mimic malignancy on US but can be safely managed with testis-sparing surgery when correctly identified (20). This further underscore the importance of refining diagnostic pathways.

Our study also emphasizes that integrating MRI into the diagnostic algorithm ensures optimal patient management. Multiparametric MRI not only enhances diagnostic precision but also provides valuable information for surgical planning, particularly in candidates for testis-sparing surgery Art 10. Furthermore, advanced MRI techniques such as diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping have shown particular promise in differentiating benign from malignant lesions (12).

When contextualized within regional practice, the results highlight a pressing need for locally tailored diagnostic guidelines. While international societies such as the European Society of Urogenital Radiology recommend MRI following inconclusive US (12), in resource-limited settings such as Pakistan, cost and accessibility constraints may hinder universal application. Thus, US should remain the primary diagnostic tool, but clinicians must maintain a low threshold for referral to MRI in cases of diagnostic uncertainty or suspected malignancy. Incorporating MRI selectively after initial US assessment enables more accurate diagnosis, supports appropriate surgical planning, and may help avoid unnecessary radical procedures, ultimately improving patient outcomes.

CONCLUSIONS

US remains a reliable and accurate first-line modality in the evaluation of suspected testicular tumors, demonstrating high sensitivity and an overall diagnostic accuracy. Key sonographic indicators of malignancy on ultrasound included hypoechogenicity, heterogeneous echotexture, and irregular lesion margins. MRI provided superior tissue characterization and functional assessment, reinforcing its role as the gold-standard modality, particularly in equivocal or complex cases.

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