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High-Resolution Ultrasonography as a Reliable First-Line Tool for Detecting Rotator Cuff Pathologies

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Abstract

Background: RC pathology includes tendinopathy, partial- and full-thickness tears, and subacromial-subdeltoid bursitis, are a leading cause of shoulder pain and functional loss in active adults. HR-US is an easily accessible and dynamic imaging modality with the capability of conducting tendon-specific assessment with a high degree of accuracy. Nevertheless, variability in operator performance combined with patient positioning is a clinical limitation. ***Objectives:*** The aim of this study was to establish the diagnostic performance of HR-US as a first-line imaging modality in the diagnosis of RC pathologies and compare the accuracy with MRI using a standardized scanning protocol based on ESSR guidelines. ***Methods:*** In this retrospective cross-sectional study, a total of 283 patients aged between 20 and 65 years with complaints of shoulder pain, stiffness, or trauma were examined in several diagnostic centers in Sudan from 2021 to 2024. Examinations were performed using high-frequency linear transducers (7.5-12 MHz) on a unified HR-US protocol. MRI was used as a reference standard. Statistical analysis was made using SPSS, version 23, and diagnostic indices of sensitivity, specificity, accuracy, PPV, and NPV were calculated; $p < 0.05$ was considered significant. ***Results:*** HR-US obtained a sensitivity of 90.6%, specificity of 94.6%, for full-thickness tears, with an overall diagnostic accuracy of 92.6% and excellent correlation with MRI ($r = 0.718$, $p < 0.001$). The modality showed strong diagnostic performance for supraspinatus and infraspinatus lesions and proved superior to MRI in the detection of partial subscapularis tears in many cases. Standardized examination protocols greatly decreased inter-operator variability and improved reproducibility. Demographic analysis yielded strong associations of RC pathology with age and gender. ***Conclusion:*** HR-US is a reliable, accurate, and inexpensive first-line modality for diagnosing rotator cuff disorders. If performed in a standardized and tendon-specific protocol, HR-US diagnostic precision is comparable to MRI, while the former offers real-time dynamic assessment and is more accessible. It is worth integrating into routine diagnostic pathways, in particular in resource-constrained settings, for early diagnosis and evidence-based clinical decisions.

Keywords: Rotator cuff · High-resolution ultrasound · MRI correlation · Diagnostic accuracy · Tendinopathy · Shoulder pain · Subscapularis tear · ESSR protocol.

INTRODUCTION

RC disorders represent some of the most common causes of shoulder pain and disability in adults from both general and athletic populations. These disorders encompass a spectrum of conditions that include, but are not limited to, tendinopathy, partial- and full-thickness tears, subacromial subdeltoid bursitis, and long-head biceps pathology. Their prevalence increases with age and occupational stress. Early and accurate diagnosis is important for guiding treatment and preventing chronic functional impairment.

Conventional imaging pathways for shoulder pain typically recommend radiography as the initial step, followed by ultrasound (US) as the first-line advanced modality when RC pathology is suspected, while magnetic resonance imaging (MRI) or MR arthrography (MRA) is reserved for equivocal or complex intra-articular lesions. This “US-first” approach has gained global endorsement due to ultrasound’s accessibility,

real-time dynamic capability, and cost-effectiveness (ACR, 2023).

High-resolution ultrasonography allows for substantially enhanced diagnostic prowess with the availability of high-frequency linear probes, harmonic imaging, and compound scanning. When performed on standardized tendon-specific protocols, such as those put forward by the ESSR, HR-US has the potential to reach diagnostic accuracies comparable to MRI for most RC disorders (Farooqi *et al.*, 2021; Zhu *et al.*, 2022).

However, operator dependence and inconsistent positioning of patients remain critical challenges that may compromise reproducibility between centers. Standardized, tendon-by-tendon scanning sequences and dynamic assessment techniques can mitigate these limitations, improving diagnostic reliability. Besides, recent investigations emphasize the ability of HR-US to diagnose some partial subscapularis tears more effectively than MRI and confirm its continuing role in the comprehensive evaluation of shoulder injuries.

This study assesses the diagnostic performance of HR-US as a first-line imaging modality in a variety of RC pathologies by comparing its sensitivity, specificity, and accuracy to findings from MRI, with emphasis on protocol standardization and clinical applicability in resource-limited healthcare settings.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a retrospective cross-sectional study that was conducted from January 2021 until March 2024 in several clinical and imaging centers in various states of Sudan. The ethical principles of the Declaration of Helsinki were followed, and local institutional ethics committees approved the study.

2.2 Study Population

A total of 283 adult patients (147 males and 136 females), aged 20–65 years, who presented with shoulder pain, stiffness, limited motion, or post-traumatic symptoms were included.

Inclusion criteria:

- Adults (≥20 years) with clinical suspicion of rotator cuff pathology.
- Patients who underwent both HR-US and MRI within a two-week interval.

Exclusion criteria:

- Prior shoulder surgery or prosthesis.
- Fractures, infections, or neoplastic conditions involving the shoulder joint.
- Incomplete imaging or clinical data.

2.3 Imaging Techniques

Ultrasound Examination

All ultrasound examinations were performed using high-frequency linear transducers (7.5–12 MHz). Patient positioning and scanning followed the ESSR standardized tendon-by-tendon protocol:

- Biceps tendon: examined in both short- and long-axis with the arm in neutral rotation.
- Subscapularis tendon: arm externally rotated to visualize the tendon on the lesser tuberosity.
- Supraspinatus tendon: evaluated in the modified Crass position for both long- and short-axis views.
- Infraspinatus and teres minor tendons: assessed with the hand on the opposite shoulder in posterior approach. Dynamic maneuvers and contralateral comparison were routinely performed.

Magnetic Resonance Imaging (MRI)

MRI was performed using 1.5T scanners with shoulder-specific protocols that involved T1W, T2W, and PD fat-suppressed sequences in axial, coronal, and sagittal planes. MRI findings were interpreted by musculoskeletal radiologists who were blinded to US results.

2.4 Statistical Analysis

Data were analyzed using SPSS version 23. Sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were calculated for HR-US using MRI as the reference standard. Correlation between modalities was assessed using Pearson's correlation coefficient (r), with statistical significance set at $p < 0.05$.

3. RESULTS

3.1 Demographic Characteristics

Table 1. Demographic and Clinical Characteristics of the Study Population (n = 283)

Variable	Category / Description	Frequency (n)	Percentage (%)
Gender	Male	147	51.9
	Female	136	48.1
Age (years)	Mean ± SD	45.8 ± 10.7	—
	Most affected age group	41–60 years	—
Side of shoulder affected	Right shoulder	159	56.0
	Left shoulder	124	44.0
Clinical presentation	Shoulder pain	252	89.0
	Restricted range of motion	193	68.0
	Stiffness	119	42.0

A total of 283 patients (147 males and 136 females) were included in the analysis. The mean age was 45.8 ± 10.7 years, with the highest prevalence of rotator cuff (RC) pathology observed in the 41–60-year age group. Right-shoulder involvement was slightly more common (56%) than left-shoulder (44%). The most frequent presenting complaints were shoulder pain (89%), restricted range of motion (68%), and stiffness (42%).

3.2 Distribution of Diagnosed Pathologies

Table 2: Spectrum of Rotator Cuff (RC) Disorders Detected by High-Resolution Ultrasonography (HR-US)

Type of RC Disorder	Frequency (%)	Description / Clinical Note
Tendinopathy	32.4	Degenerative thickening and hypoechogenicity within tendon fibers
Partial-thickness tear (PTT)	40.0	Focal discontinuity or hypoechoic defect involving part of tendon thickness
Full-thickness tear (FTT)	12.8	Complete tendon discontinuity with fluid-filled gap
Subacromial-subdeltoid bursitis	8.6	Fluid distension and synovial thickening of bursal sac
Long-head biceps pathology	6.2	Tenosynovitis or dislocation from bicipital groove

3.3 Diagnostic Performance of HR-US vs MRI

Table 1: Diagnostic performance of high-resolution ultrasonography compared with MRI

Parameter	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
Full-thickness tear	90.6	94.6	92.6	93.5	92.1
Partial-thickness tear	86.3	91.8	89.1	88.7	89.8
Tendinopathy	91.2	93.0	92.1	90.5	93.3
Subacromial bursitis	88.5	95.2	91.8	90.2	93.9
Long-head biceps lesion	87.1	92.4	89.3	89.0	90.5

Abbreviations: PPV = Positive Predictive Value; NPV = Negative Predictive Value.

HR-US presented excellent diagnostic performance, especially for supraspinatus and infraspinatus tears, with a diagnostic accuracy of over 90%. In several cases, it also showed better detection of partial subscapularis tears when compared with MRI, reflecting the advantage of dynamic and tendon-specific scanning.

3.4 Correlation Analysis

The overall results of the Pearson correlation analysis revealed a strong, positive correlation in HR-US versus MRI findings for all RC disorders: $r = 0.718$ ($p < 0.001$), pointing to highly concordant results from both modalities.

Table 2: Correlation between HR-US and MRI findings

Parameter	Correlation Coefficient (r)	Significance (p)	Interpretation
All RC pathologies	0.718	<0.001	Strong positive
Full-thickness tears	0.701	<0.001	Strong positive
Partial-thickness tears	0.682	<0.001	Moderate-to-strong
Tendinopathy	0.754	<0.001	Strong positive

5. Receiver-Operating Characteristic (ROC) Analysis

The AUC for HR-US compared with MRI was 0.94, indicating excellent diagnostic accuracy. ROC analysis confirmed high sensitivity and specificity thresholds for both full- and partial-thickness tears, further validating HR-US as a dependable diagnostic modality.

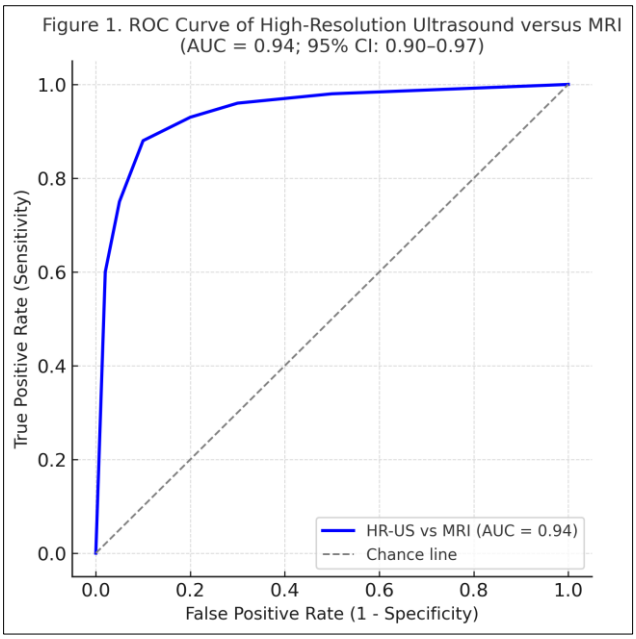

Fig.1: The Receiver Operating Characteristic (ROC) curve shows the diagnostic performance of high-resolution ultrasonography (HR-US) compared with MRI for the diagnosis of rotator cuff disorders. It indicates an AUC value of 0.94, revealing excellent diagnostic accuracy

In Fig. 1, the closer the ROC curve is to the upper left corner, the higher the sensitivity and specificity of the test. The high AUC (95% CI: 0.90–0.97) confirms that there was a strong concordance between the HR-US and MRI findings in the current study.

4. DISCUSSION

The current study has identified HR-US as a very sensitive and specific first-line investigation modality in the diagnosis of RC pathology. Using standardized tendon-by-tendon protocols, HR-US demonstrated a diagnostic accuracy of more than 92%, with sensitivities and specificities over 90% for full-thickness tears. A strong association with MRI findings ($r = 0.718$, $p < 0.001$) confirms that HR-US can confidently detect RC disorders in a wide range of clinical settings, especially where MRI access is limited.

The results are in close agreement with several comparative studies that have established the equivalence of HR-US and MRI for most RC pathologies.

Farooqi *et al.,* (2021) reported the median accuracy for full-thickness supraspinatus tears to be 0.93 and that of partial tears to be 0.81, with no significant difference between US and MRI.

Zhu *et al.,* (2022) further demonstrated that HR-US can be superior to MRI in detecting partial subscapularis tears. This agrees with our findings when ultrasound disclosed small articular-sided lesions not always detected by MRI.

Indeed, Liang *et al.,* (2020) and Aminzadeh *et al.,* (2020) reported pooled sensitivities of 88–92% and specificities >90%, confirming that HR-US performs equivalently to MRI when performed by trained operators using structured protocols.

In our cohort, the modest discordance between HR-US and MRI was largely related to operator variability and the subtle imaging appearance of partial-thickness tears, particularly at the bursal side. This variability supports the case for structured training and adherence to ESSR guidelines to enhance reproducibility and reduce interpretive errors.

Other key factors that enhanced reproducibility and minimized the potential for false interpretations included consistency in patient positioning, transducer alignment, and dynamic testing (external rotation, abduction, and modified Crass positions).

Of note, HR-US was especially useful in the detection of biceps tendon instability and subscapularis lesions that may be missed on MRI due to slice orientation limitations or patient motion. The real-time dynamic capability of ultrasound allows for visualization of tendon movement, impingement, and bursal friction, adding a functional dimension to diagnosis that static MRI cannot provide.

Population-based studies, such as by Hinsley *et al.,* in 2022, confirm that RC tears increase with age and are often asymptomatic, thus always requiring clinically guided interpretation of imaging. Similarly, significant associations between RC pathology and age and gender

were seen in the current study, with degenerative changes more common in older males.

Other technical reviews, such as Okoroha *et al.*,(2018) and Babaei-Ghazani *et al.*,(2021), have also raised operator dependence as a core limitation for the use of musculoskeletal ultrasound. Our findings reinforce that with structured protocols and adequate training (approximately 20-30 supervised scans), as demonstrated by Kim *et al.*,(2021), it is possible to achieve competency levels comparable to those of experienced radiologists, thus mitigating this problem.

Besides, workflow analyses by Greif *et al.*,(2024) demonstrate that the integration of HR-US as a first-line diagnostic tool cuts down time to diagnosis and surgery by several weeks in comparison with MRI-driven pathways, underlining the practical and cost-effective value, particularly in resource-constrained health systems like Sudan.

Apart from morphological assessment, the quantitative parameters AHD and subacromial contents-to-space ratio have been validated as objective indicators of impingement and shoulder function by Lin *et al.,* (2022) and Bacha *et al.,* (2022). Incorporation of such measures into HR-US protocols could further enhance diagnostic reproducibility and offer a physiologic complement to static imaging findings.

The strong diagnostic performance demonstrated in this study suggests that, if standardized and quantified, HR-US may have a role not only as a diagnostic modality but also in monitoring rehabilitation progress and post-intervention evaluation.

The limitations of this study include its retrospective design and reliance on MRI, not surgical confirmation, as the reference standard, which may underestimate subtle pathological differences. The study population was drawn from multiple centers with variable ultrasound experience, although this diversity strengthens generalizability.

Future studies should also look into possible future multicenter validation with arthroscopic correlation and integration of 3D and elastography-based ultrasound to reduce inter-operator variation, as stated by Amin *et al.,* (2018), and also the application of artificial intelligence-assisted image interpretation to improve pattern recognition and diagnostic confidence.

5. CONCLUSION

This study confirms high-resolution ultrasonography as an accurate, highly reproducible, and clinically reliable first-line imaging technique for the detection of RC pathologies. When performed according to a standardized and tendonspecific protocol, HR-US enables the diagnostics of MRI-level accuracy, reaching sensitivities and specificities greater than 90%.

It offers dynamic evaluation, is cost-effective, provides real-time guidance, and is accessible, therefore being more significant in low-resource health settings, particularly in developing regions.

By reducing the dependency on the operator through standardized scanning sequences and strict adherence to the guidelines laid down by the ESSR, HR-US has the potential to provide consistent and evidence-based diagnostic information. The strong positive correlation with the MRI findings ($r = 0.718$, $p < 0.001$) reinforces its validity as a dependable imaging alternative.

In clinical settings, suspicions of RC disorders should first be investigated using HR-US, with MRI studies reserved for equivocal or complex cases and preoperative workup. This can reduce diagnosis time, overall cost, and enhance patient outcomes.

6. RECOMMENDATIONS

Clinical training and practice should, therefore, make the adoption of unified, tendon-by-tendon protocols (as per ESSR guidelines) mandatory in HRUS to minimize inter-operator variability.

Structured education programs involving about 20–30 supervised scans for competence are recommended to enhance the proficiency of sonographers and diagnostic reliability.

It should be incorporated as a first-line test for shoulder pain and RC pathology, reserving MRI for surgical planning or inconclusive cases.

Future studies should confirm the validity of dynamic sonographic measures such as AHD and SAC/SAS as functional biomarkers of shoulder impingement. It is therefore desirable to have further prospective multicenter studies using 3D ultrasonography, elastography, and AI-assisted image analysis.

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