ORIGINAL ARTICLE

Early career accuracy of shoulder ultrasound in evaluating rotator cuff tendon tears

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ABSTRACT

Aim To compare the accuracy of shoulder ultrasound (US) in diagnosing rotator cuff tendon tears between junior and experienced musculoskeletal (MSK) radiologists. Also, to compare the overall ultrasound accuracy referenced to MRI.

Methods A retrospective data collection for patients with clinically suspected rotator cuff tears who underwent ultrasound from June 2021 - June 2023 was conducted. Patients who also performed MRI for the same shoulder were only included in the study. US and MRI images were evaluated by two MSK radiologists with different experience levels. The diagnosis of rotator cuff tears was done on MRI through consensus. Ultrasound accuracy referenced to MRI was calculated for each radiologist. A second consensus was conducted for US images to calculate the overall US accuracy. The percentage of agreement and Cohen's kappa correlation coefficient were calculated before and after the US consensus.

Results Forty-one patients were included in the study, 12 (29.3%) males and 29 (70.7%) females, with a mean age of 49.6 years. Sensitivity, specificity, positive (PPV) and negative predictive values (NPV), and accuracy of US interpreted by junior vs experienced MSK radiologists for supraspinatus full thickness tears (FTTs) were 100% vs 91%, 90% vs 93%, 79% vs 83%, 100% vs 97%, and 93% vs 93%, respectively. After the second consensus, sensitivity, specificity, PPV and NPV, and accuracy were 91%, 90%, 77%, 96%, and 90%, respectively.

Conclusion The accuracy of shoulder ultrasound in diagnosing supraspinatus FTTs by junior MSK radiologists compares well to the more experienced ones, but not for partial thickness tears (PTTs).

Key words: magnetic resonance imaging, rotator cuff injuries, retrospective studies, shoulder, ultrasound

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Original submission:
05 December 2023;
Accepted:
20 December 2023
doi: 10.17392/1702-23

Med Glas (Zenica) 2024; 21(1):190-195

INTRODUCTION

Shoulder pain is the third commonest cause of musculoskeletal (MSK) pain after low back pain and knee pain, and it results in significant disability and reduced quality of life (1). In patients with shoulder pain, rotator cuff disease is the most common cause, present in approximately 85% of patients (2,3). Rotator cuff tears (RCTs) account for almost 50% of major shoulder injuries but are sometimes difficult to diagnose (4).

Ultrasound (US) and magnetic resonance imaging (MRI) are used to evaluate the type and extent of RCTs. While MRI is well-validated to both radiologists and orthopaedic surgeons in this regard, US use remains controversial among both specialties, as it has a few limitations like operator dependence (5), the pre-requisite requirement for special training, as well as the need for state-of-the-art sonographic equipment. This is evidenced by the fact that only about 55% of shoulder surgeons in the United States trust US as the first imaging modality for diagnosing RCTs (6). However, previous studies about US for this purpose have continuously shown strong evidence of its high capability to discriminate different RCTs (7-10).

In our study we aim to increase the confidence of both radiologists and orthopaedic surgeons, in the use of US for diagnosing RCTs, and that is, by comparing the accuracy of shoulder US between junior and experienced MSK radiologists, with MRI as a reference. This can encourage more radiologists to seek special training in shoulder US knowing that it has a rapid learning curve, and at the same time, it can increase orthopedic surgeons' trust in the use of US, especially for diagnosing the surgically more important full-thickness tears (FTTs), knowing that they can be picked even in the hands of the less experienced. To the best of our knowledge, this is the first study comparing shoulder US accuracy in diagnosing RCTs between early career and experienced MSK radiologists.

The aim of this study was to compare the accuracy of US in diagnosing rotator cuff tendon tears between junior and experienced musculoskeletal radiologists, as well as to compare the overall ultrasound accuracy referenced to MRI.

PATIENTS AND METHODS

Patients and study design

All patients with clinically suspected RCTs, referred by the Shoulder Orthopaedic Specialist Clinic at King Abdullah University Hospital, and who underwent US for the symptomatic shoulder from June 2021 to June 2023 were reviewed. Only those patients with an MRI of the ipsilateral shoulder performed at our centre were included in the study. Demographic and clinical data were retrospectively collected.

The institutional review board at the Jordan University of Science and Technology approved this study and waived the need for a written consent (Approval No. 1/150/2022, 21/07/2022).

Methods

All US examinations were performed on a Toshiba machine (Aplio 500, Toshiba Corporation, Minato, Tokyo, Japan) using a linear transducer probe with a frequency range of 5-14 MHz. All exams were done using a dedicated US software preset for the shoulder, and through a standard scanning protocol that includes external rotation of the shoulder for visualizing the subscapularis tendon, and internal rotation and extension for visualizing the supraspinatus and infraspinatus tendons (Crass position).

MRIs were performed on either 1.5T or 3T Phillips machines (Ingenia or Achieva, respectively, Best, The Netherlands) depending on availability at the time of the study. A dedicated shoulder coil was used in all cases. All included a combination of fluid-sensitive sequences with and without fat saturation in axial, coronal oblique, and sagittal oblique imaging planes. The slice thickness for all sequences was 3 mm with an interslice distance of 0.3 mm. The imaging matrix was 320 x 223.

Two fellowship-trained MSK radiologists interpreted US and MRI images, one with about 2 years of experience post-fellowship, and the other with more than 7 years of experience. The diagnosis of partial-thickness tears (PTTs) and FTTs were made on MRI through consensus. The PTT was defined as a T2 bright or intermediate signal defect in the rotator cuff tendon that affects either the bursal or articular side regardless of the loca-

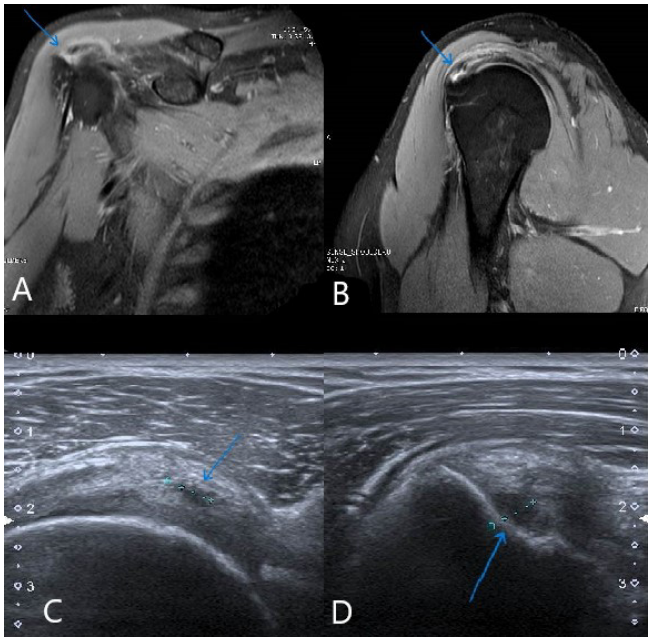

Figure 1. Bursal-sided partial-thickness tear (PTT) in the supraspinatus tendon anteriorly seen on A) coronal oblique and B) sagittal oblique proton density spectral adiabatic inversion recovery magnetic resonance (PD SPAIR MR) images, and on C) transverse and D) longitudinal ultrasound (US) images (King Abdullah University Hospital, 2022)

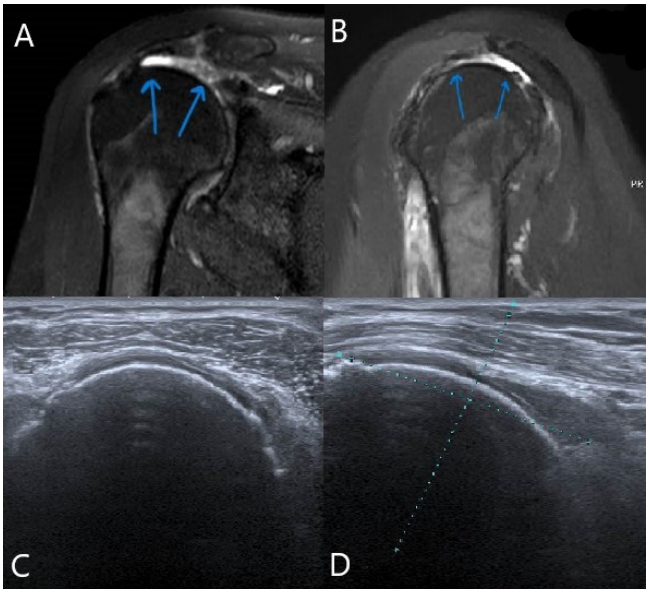

Figure 2. Complete full-thickness tears (FTT) in the supraspinatus tendon with retraction seen on A) coronal oblique and B) sagittal oblique T2 spectral adiabatic inversion recovery magnetic resonance (T2 SPAIR MR) images, as well as on C) transverse and D) longitudinal ultrasound (US) images (King Abdullah University Hospital, 2021)

tion, percentage of the affected thickness or width (Figure 1A and 1B). Similarly, the FTT was defined as a T2 bright or intermediate signal defect in the rotator cuff tendon that extends between the bursal and articular sides regardless of the location or affected width (Figure 2A and 2B). The second consensus was done for US images using the same definitions of PTT and FTT but using ultrasound terminology (i.e., anechoic, or hypoechoic defect, respectively) (Figure 1C and 1D, Figure 2C and 2D).

Statistical analysis

Sensitivity, specificity, positive and negative predictive values (PPV and NPV), and accuracy for FTT and PTT of the rotator cuff tendons were calculated. Two sets of calculations were obtained before and after US consensus (to compare

accuracy parameters for the junior vs experienced radiologists before consensus and between the two imaging modalities after consensus). Percentages of agreement and Cohen's Kappa correlation coefficients were calculated using an online calculator tool (https://idostatistics.com/cohen-kappa-free-calculator/) for both radiologists before US consensus and for both imaging modalities after US consensus.

RESULTS

A total of 41 patients fulfilled the inclusion criteria and were included in the study. There were 12 (29.3%) males and 29 (70.7%) females, with a mean age of 49.6 years (range 15 – 86); 29 (71%) patients were right-handed, four (10%) were left-handed. Hand dominance data were not documented for eight (19%) patients. The number of normal supraspinatus tendons in our cohort was 18, the number of supraspinatus FTT was 11, and the number of supraspinatus PTT was 12.

Sensitivity, specificity, PPV and NPV, and accuracy of shoulder US in diagnosing supraspinatus FTT by the junior vs experienced MSK radiologists were 100% vs 91%, 90% vs 93%, 79% vs 83%, 100% vs 97%, and 93% vs 93%, respectively (Table 1).

Sensitivity, specificity, PPV and NPV, and accuracy of shoulder US in diagnosing supraspinatus PTT by the junior vs experienced MSK radiologist were 50% vs 58%, 79% vs 86%, 50% vs 64%, 79% vs 83%, and 71% vs 78%, respectively (Table 1).

Table 1. Accuracy of ultrasound (US) in diagnosing rotator cuff tears (RCTs) for junior vs experienced musculoskeletal (MSK) radiologists (before US consensus)

Variable	Junior radiologist		Senior radiologist	
	FTT	PTT	FTT	PTT
Sensitivity (%)	100	50	91	58
Specificity (%)	90	79	93	86
PPV (%)	79	50	83	64
NPV (%)	100	79	97	83
Accuracy (%)	93	71	93	78

FTT, full thickness tears; PTT, partial thickness tears; PPV, positive predictive value; NPV, negative predictive value;

Overall sensitivity, specificity, PPV and NPV, and accuracy of shoulder US compared to MRI in diagnosing supraspinatus FTT and PTT were 91% and 58%, 90% and 76%, 77% and 50%, 96% and 82%, and 90% and 71%, respectively (Table 2).

Table 2. Accuracy of ultrasound (US) in diagnosing rotator cuff tears (RCTs) referenced to magnetic resonance imaging (MRI) (after US consensus)

Variable	FTT	PTT
Sensitivity (%)	91	58
Specificity (%)	90	76
PPV (%)	77	50
NPV (%)	96	82
Accuracy (%)	90	71

FTT, full thickness tears; PTT, partial thickness tears; PPV, positive predictive value; NPV, negative predictive value;

The insufficient number of tears in our study population for the infraspinatus and subscapularis tendons precluded calculating accuracy for these tendons.

The percentage of agreement for US readings between radiologists before US consensus was 0.81 (Cohen's kappa = 0.65 for any type of tear - substantial agreement; 0.89 for FTT - almost perfect agreement; 0.58 for PTT - moderate agreement). The percentage of agreement between US and MRI readings after US consensus was 0.68 (Cohen's kappa = 0.49 for any type of tear - moderate agreement; 0.77 for FTT - substantial agreement; 0.33 for PTT - fair agreement).

DISCUSSION

The use of US in evaluating rotator cuff tendons has been of increased scientific interest in the last one or two decades, with multiple publications present in the literature comparing US with other diagnostic modalities such as MRI, MR arthrogram, or arthroscopy (10-12). Furthermore, the evolution of real-time sonoelastography (RTSE) has paralleled this scientific interest, adding an extra prognostic value in patients with RCTs by evaluating tissue stiffness, and that is through implementing the strain elastography index into the sonographic exam (13).

Since the first reported use of ultrasound in the shoulder by Mayer in 1977 (14) orthopaedic surgeons, and radiologists interested in MSK US, conducted multiple studies to confirm its usefulness in diagnosing different rotator cuff pathologies, especially RCTs. In 1985, Middleton et al. published the first article specifically studying the diagnosis of RCTs by US (15). Ever since and guided by the gradual advancements in sonographic machinery and technique, ultrasound has achieved comparable accuracy nearly equal to MRI in the diagnosis of both FTTs and PTTs at a much lower cost (16). However, despite the

strong evidence present to date, US use in this regard has not been widely accepted by the shoulder orthopaedic community.

FTTs are surgically more important than PTTs (17), obviously due to their greater impact on the shoulder's function and not just the major complaint of shoulder pain. Most of the previously published studies have unequivocally shown that US has a very high accuracy in diagnosing FTTs, with relatively less accuracy for PTTs (17). These concord with our results, even when evaluating those of the junior MSK radiologist. We believe that this trend of results in the literature suggests the safe use of US as a screening tool for triaging patients into surgical and non-surgical and hence guiding the clinical decision (i.e., surgical vs conservative management). This is supported by many previous studies that recommended US as the first imaging modality for diagnosing RCTs (10-12, 17).

To further strengthen the rationale behind using US in the initial assessment of RCTs, we compared its accuracy between two MSK radiologists of different experience levels, one with almost 2 years of experience, and the other with more than 7 years. Through this methodology, we aimed to prove the ability of an US-trained MSK radiologist to safely convey the diagnosis of the surgically more important FTTs early in his career. For instance, the specificity, PPV, and accuracy of US in diagnosing supraspinatus FTT by the junior MSK radiologist were 90%, 79%, and 93%, respectively, which were nearly equally comparable to those of the experienced (93%, 83%, and 93%, respectively). Furthermore, the sensitivity and NPV were unexpectedly higher for the junior vs experienced radiologists for supraspinatus FTT though they remain comparable (100% vs 91%, and 100% vs 97%, respectively).

On the other hand, the accuracy of US in confirming the diagnosis of PTTs by the junior radiologist was not promising. Despite the acceptable results obtained by the junior radiologist compared to those published in the literature, the difference between the two remained relatively high. For example, the sensitivity and PPV for the junior vs experienced radiologists were 50% vs 58%, and 50% vs 64%, respectively. This indicates that PTT is a challenging US diagnosis compared to FTT, as previously reported in the literature (18).

On the contrary, the accuracy parameters that rely on negative US scans (specificity and NPV) were higher for both levels of experience, with a lesser difference (79% vs 86%, and 79% and 83%, respectively). This suggests that US can be a valuable tool in ruling out PTTs.

The reported sensitivity of US across multiple previous studies in the literature ranged between 52-100% and 13-100% for detecting FTTs and PTTs, respectively (19-22), while the specificity ranged between 53-100% and 40-100% (23-26). Our results lie within these ranges with a calculated sensitivity and specificity of 91% and 90% for FTTs, and 58% and 76% for PTTs, respectively. Cohen's kappa correlation coefficient between the two modalities in our study is 0.49, which is classified as moderate agreement (27). This is lower than the previously reported one by Singh et al. (11), which was 0.79 (good agreement), probably due to the methodology of our study aiming to compare radiologists of different levels of experience. However, Cohen's kappa correlation coefficient between the two radiologists is 0.65, which is classified as substantial agreement (27). This last result enhances the concept of US safety early in the MSK radiologist's career.

The limitations of this study are the following: a retrospective collection of data, arthroscopy was not performed for most of the included patients, the dimensions of tears were not considered in statistical analysis, all patients were referred from a shoulder orthopaedic clinic, mixed clinical history of included patients with traumatic and atraumatic indications for imaging, a wide range of age distribution (15 – 86 years), and the small sample size.

In conclusion, the accuracy of shoulder ultrasound in diagnosing FTTs by junior MSK radiologists compares well to the more experienced ones, indicating a rapid learning ability and the safety of ultrasound in diagnosing the surgically more important type of RCTs. However, PTTs remain a challenge for both levels, though US remains a good tool in ruling out this type of tears.

ACKNOWLEDGMENT

We acknowledge the assistance we received from the student at the Faculty of Medicine, Leen Sawalha, while collecting data for patients included in the study.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATION

Competing interests: None to declare.

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