Original Article

The Value of Ultrasound Performed by a Physiatrist in the Detection of Supraspinatus Tendon Tears Diagnosed Using Magnetic Resonance Imaging

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ABSTRACT

Objectives: To assess the sensitivity and specificity of shoulder ultrasound (US) performed by a physiatrist for detecting supraspinatus tendon tears using magnetic resonance imaging (MRI) as a reference standard.

Study design: Diagnostic research with retrospective data collection.

Setting: The rehabilitation medicine outpatient clinic, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima Province, Thailand.

Subjects: Patients over 18 years old with shoulder pain clinically suspected of having a rotator cuff tear who underwent shoulder US and MRI.

Methods: The US was performed by a physiatrist who had completed a 1-month clinical observational course of the musculoskeletal US training program. The MRIs were accomplished by two general radiologists. A physiatrist, who was not an ultrasonographer, reviewed all patients' data from the hospital records. A cross-table comparison was conducted between US assessment and MRIs of the supraspinatus tendon. Sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were calculated. A total of 65 patients were included in the study.

Results: The US performed by a physiatrist showed a sensitivity of 84.4% and specificity of 100% in detecting all-type supraspinatus tendon tears. The sensitivity and specificity in detecting full-thickness tears were 88.5% and 82.9%, respectively, and 55.3% and 89.7%, respectively, in detecting partial-thickness tears.

Conclusions: Shoulder US by a trained physiatrist showed high sensitivity and specificity for detecting supraspinatus tears diagnosed by MRI. Trained clinicians who are new to musculoskeletal ultrasound could use this method in the clinical-based evaluation of supraspinatus tendon tears for initial diagnosis and management.

Keywords: supraspinatus tendon tear, ultrasound, magnetic resonance imaging, physiatrist

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Introduction

Shoulder pain is a common problem in the outpatient department. It has been found in 16-34% of the general population,[1] with rotator cuff tear as the most common cause of shoulder pain. The supraspinatus tendon is the structure most frequently involved and the first tendon to be injured.[2] Magnetic Resonance Imaging (MRI) of the shoulder is now the imaging gold standard for this condition due to its high sensitivity and accuracy. The Cochrane Database of Systematic Reviews reported that the sensitivity and specificity of MRI for diagnosing rotator cuff tears were 98% and 79%, respectively.[3] However, MRI has the disadvantages of high cost, requiring a long time to perform, and being contraindicated in patients with a pacemaker or who suffer from claustrophobia.

Ultrasound (US) has been used in the diagnosis of rotator cuff tears for years. It has the advantages of low cost, a relatively short duration process and greater accessibility. However, it has the limitation of being operator-dependent, although current evidence shows that US has high sensitivity (91%) and specificity (85%) when performed by a radiologist or sports orthopedist.[3-5]

For the past ten years, physiatrists in Thailand have been using US as a diagnostic tool for screening musculoskeletal disorders, followed by initial management and further investigation. Maharat Nakhon Ratchasima Hospital is a tertiary referral hospital that has a sports clinic in the orthopedic surgery department; however, no musculoskeletal US service by a radiologist is currently available at the hospital. MRI shoulder is the only imaging done for a suspected rotator cuff tear; however, the procedure has a waiting time of at least three months. Due to the high cost of MRI, it is usually performed only in selected cases where surgery is required. In the rehabilitation clinic, there are many patients with shoulder pain but without a specific diagnosis because of the limitations of investigations. US could help address this issue. Therefore, one physiatrist in the clinic participated in a 1-month clinical observational course of musculoskeletal US in 2014.

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Musculoskeletal US service in our hospital begins with a shoulder US examination to detect shoulder pathologies. The most common disorder is a rotator cuff tear. However, no information is currently available concerning the sensitivity and specificity of the US that have been performed. The aims of this study were to retrospectively compare ultrasonographic findings with MRI findings and to evaluate the accuracy of US conducted by a trained physiatrist after completing one month of training on diagnosing supraspinatus tendon tears.

Methods

This retrospective study was performed at a rehabilitation medicine outpatient clinic of a tertiary care hospital in Nakhon Ratchasima which receives 5-10 shoulder-pain cases per month. Patients with shoulder pain seen by the clinic between January 1, 2016 and December 31, 2021 were identified. Patients with a history of shoulder surgery, and no data of shoulder US or shoulder MRI were excluded from the study.

Data was collected on a total of 65 patients over age 18 with shoulder pain who were suspected of having a supraspinatus tear and who had undergone shoulder US as well as an MRI within 3 months of the US. The US was performed by a physiatrist (R.S.) who had completed a 1-month clinical observational course of the musculoskeletal US training program prior to performing US.

A physiatrist (P.C.), who did not perform US, reviewed all patient data including gender, age, side of shoulder pain, history of shoulder surgery, shoulder ultrasound reports from the Electronic Medical Record (EMR) program, and shoulder MRI reports from the picture archiving and communication system (PACS) program.

Ultrasonography

A physiatrist (R.S.), who has completed the 1-month clinical observation course of the musculoskeletal US examination training program at National Taiwan University Hospital, performed all shoulder US using a Hitachi Arietta V60 5-10 MHz linear array ultrasound transducer (38 mm). The supraspinatus tendon US examinations were performed with both patient and sonographer seated on backless stools facing each other. The patient positioned the arm in extension and internally rotated with the elbow in flexion and their hand placed on their buttock. Imaging was completed in both the long axis (sagittal plane) and the short axis (transverse plane).

Long axis: The transducer was placed parallel to the longitudinal line of the supraspinatus tendon at the greater tubercle of the humerus. A hyperechoic fibrillation pattern is seen on the humerus cortex, similar to a bird's beak.

Short axis: The transducer was rotated 90 degrees from the long axis position with the transducer perpendicular to the longitudinal line of the tendon. The image appears as a hyperechoic fibrillation pattern resembling a rainbow.[6]

Diagnosis of the supraspinatus tendon abnormality was recorded as either no tear, partial-thickness tear, or full-thickness tear. A full-thickness tear was defined as a well-defined hypoechoic or anechoic defect that disrupts the hyperechoic tendon fibers and extends from the articular to bursal surfaces of the tendon. A partial-thickness tear showed a well-defined hypoechoic or anechoic abnormality that disrupts the tendon fibers, which may be at the bursa surface, articular surface, and/or within the tendon (Figure 1). Other pathologies, e.g., tendinopathy and tendinosis, appeared as calcification and inhomogeneity of the tendon.[7-9]

Magnetic resonance imaging

MRI of the shoulder was performed following the protocol using a 1.5 Tesla magnet with a field of view of 15 cm without Gadolinium and using a T2-weighted images sequence in the axial, coronal oblique, and sagittal planes as follows:

1. Axial: T2-weighted fat-suppressed, 3D T2, T2 GRE, and proton density-weighted 3 mm thick slices with a 1 mm gap (20 slides)
2. Coronal oblique: T2-weighted fat-suppressed, proton density-weighted 3 mm thick slices with an 0.8 mm gap (20 slides)
3. Sagittal: T2-weighted fat-suppressed, proton density-weighted 3 mm-slice thickness with a 1 mm gap (20 slides)

The patients were in a supine position with the affected arm at their side in partial external rotation. The criterion for a full-thickness supraspinatus tear was a focal discontinuity in the tendon extending from the articular to the bursal side, seen as a fluid signal intensity on T2-weighted images. A partial-thickness tear was defined as an incomplete tear involving the articular side, bursal side or within the tendon appearing as high signal intensity on T2-weighted images (Figure 1).

Statistical analysis

The sample size was calculated based on a pilot study of 20 patients with shoulder pain who had undergone shoulder US and MRI. The overall prevalence of supraspinatus tears in our hospital was 0.9. The sensitivity and specificity were 0.83 and 1. We assumed a sampling error of approximately 5% and the precision of estimation was 0.1. The calculated required sample size was 60 patients.

A cross-table was constructed to compare the US assessment with the MRI of the supraspinatus tendon. We calculated the sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios. All statistical analyses were performed using STATA version 13 for Windows.

Results

Of the patients with shoulder pain, 260 shoulders received a shoulder US examination but only 67 shoulders also received a confirmatory MRI examination within 3 months of the US. The patients had a mean age of 56.9 years (SD 9.7) and there were 37 males (55.3%). The right side was affected in 35 of the cases (53.8%), 28 cases (43.1%) on the left side

Table 1. Comparison between MRI and ultrasonographic findings in the diagnosis of supraspinatus tendon tears

MRI finding	Ultrasonographic finding			Total[1]
	No tear	Partial-thickness tear	Full-thickness tear	
No tear	3	0	0	3 (4.5)
Partial-thickness tear	10	21	7	38 (56.7)
Full-thickness tear	0	3	23	26 (38.8)
Total	13	24	30	67

[1]Number (%)

and 2 cases (3.1%) on bilateral sides.

MRI examination detected supraspinatus tears in 64 shoulders, of which 26 (38.8%) had full-thickness tears and 38 shoulders (56.7%) had partial-thickness tears, while US detected supraspinatus tears in only 54 shoulders (Table 1). US showed a sensitivity of 84.4% and a specificity of 100% in detecting supraspinatus tendon tears, including partial-thickness and full-thickness tears. The positive predictive values and negative predictive values were 100% and 23.1%, respectively. The calculated the negative likelihood ratio was 0.16 but the positive likelihood ratio could not be calculated because there were no shoulders where US detected a supraspinatus tear with no tear detected by MRI (Table 2).

We further analyzed the sensitivity and specificity of US for detecting full-thickness and partial-thickness supraspinatus tears. The sensitivity and specificity of detecting full-thickness tears were 88.5% and 82.9%, respectively (Table 3). Of the full-thickness supraspinatus tears, 23 of 26 were identified correctly with US and 3 shoulders were misdiagnosed as partial-thickness tears. Two of the three false negative cases had subdeltoid bursitis.

The sensitivity and specificity of US for detecting partial-thickness tears were 55.3% and 89.7%, respectively (Table 3). US correctly identified 21 of 38 partial-thickness supraspinatus tears while ten shoulders were incorrectly underestimated as having no tears, and 7 shoulders were overestimated as full-thickness tears. Among the underestimated group, most of the partial-thickness tears were intrasubstance tears (n=2) or articular side tears (n=6), while 50% (n=5) were cases of tendinopathy or tendinosis.

Discussion

In this study, we assessed the sensitivity and specificity of clinic-based US by a physiatrist in detecting supraspinatus tears, using MRI as a reference. We found that US has high sensitivity and specificity at 84.4% and 100%, respectively, but slightly lower sensitivity compared to previous studies. For example, Cole et al., Kurz et al., and Guo et al. found that US had a sensitivity of 87- 97% and a specificity of 80-100% for detecting all-type supraspinatus tears.[10-12] The Cochrane Database of Systematic Review published by Lenza et al., which included 13 studies, reported that US has high sensitivity (91%) and specificity (85%) for detecting rotator cuff tears.[3] However, surgery was used as a reference in these studies which resulted in selection bias because only patients with severe pathology or a full-thickness supraspinatus tear underwent the surgery. The actual accuracy might be a bit higher. We believe that MRI, which has a high sensitivity (98%)[3] and specificity (86%)[13] can help eliminate this bias, but it is not a perfect reference test that may affect the estimate of accuracy.

The specificity of US for detecting supraspinatus tears in our study was 100% which may have been a result of the small sample size. There were only three shoulders with no supraspinatus tears and no shoulders where US detected a supraspinatus tear but no tear was detected by MRI (false positive), hence we could not calculate the positive predictive value (PPV), one of the limitations of our study.

Table 2. Sensitivity, specificity, likelihood ratio and predictive value, and 95% CI of ultrasound in detecting supraspinatus tendon tears

MRI finding	All types of tears
Sensitivity[1]	84.4 (73.1-92.2)
Specificity[1]	100 (29.2-100)
Positive likelihood ratio[2]	-
Negative likelihood ratio[2]	0.16 (0.09 -0.28)
Positive predictive value[1]	100 (93.4-100)
Negative predictive value[1]	23.1 (5.0-53.8)

[1]% (95% confident interval), [2]ratio (95% confident interval)

Table 3. Sensitivity, specificity, likelihood ratio, predictive value and 95% CI of ultrasound in detecting partial-thickness and full-thickness supraspinatus tendon tears

	Partial-thickness tear	Full-thickness tear
Sensitivity[1]	55.3 (38.3-71.4)	88.5 (69.8-97.6)
Specificity[1]	89.7 (72.6-97.8)	82.9 (67.9-92.8)
Positive likelihood ratio[2]	5.34 (1.76-16.2)	5.18 (2.6-10.3)
Negative likelihood ratio[2]	0.49 (0.34-0.73)	0.14 (0.048-0.41)
Positive predictive value[1]	87.5 (67.6-97.3)	76.7 (57.7- 90.1)
Negative predictive value[1]	60.5 (44.4- 75)	91.9 (78.1-98.3)

[1]% (95% confident interval), [2]ratio (95% confident interval)

We also analyzed the sensitivity and specificity of US for detecting each type of supraspinatus tear. We found high sensitivity (88.5%) and high specificity (82.9%) in detecting full-thickness tears but low sensitivity (55.3%) and high specificity (89.7%) in detecting partial-thickness tears. Our results are similar to those reported in previous studies. In a systematic review by Farooqi et al., ultrasound showed a sensitivity of 88% and specificity of 93% for detecting a full-thickness tear of the rotator cuff, and a sensitivity of 65% and specificity of 86% for detecting a partial-thickness tear.[5]

In 10 of 38 shoulders (26%), US missed a supraspinatus tear which was identified by MRI as a partial-thickness tear. The location of the lesion was an important factor in the misinterpretation. Intrasubstance tears and articular side tears are difficult to detect, especially in small lesions.[14,15] For the underestimated group in this study, we consulted the radiologist to get further information regarding the tear's location. There were 2 shoulders with intrasubstance tears and 6 shoulders with articular side tears (Figure 2). Waldt et al. found that the ability to detect small partial-thickness supraspinatus tears by US was limited due to it being difficult to distinguish them from tendinopathy or tendinosis.[16] Tendinopathy was seen as hypoechoic as well. Moreover, a calcified tendon causes an error in interpretation because the calcified stone reflects ultrasound waves, allowing less energy to pass through the area behind it, like an acoustic shadow obscuring the lesion. Our study found 5 shoulders with tendinopathy or calcification in the underestimated group.

Another reason that US had low sensitivity in detecting partial-thickness supraspinatus tears was the overestimation of tears using ultrasound with some partial-thickness tears being identified as full-thickness tears. There were 7 of 38 shoulders (18%) with this error type. Teefy et al. reported that extensive partial-thickness tears involving greater than 50% of the cuff resemble full-thickness tears because the structures of the rotator cuff are deformed.[17]

The sensitivity of US for detecting full-thickness supraspinatus tears was higher than that for partial-thickness tears. We missed only 3 of 26 shoulders (11%) with full-thickness tears that ultrasound revealed to be partial-thickness tears. Rutten et al. conclude that the misinterpretation may be caused by granulation or that bursal synovial tissue may fill in a full-thickness tear, thereby impeding sonographic visualization.[18]

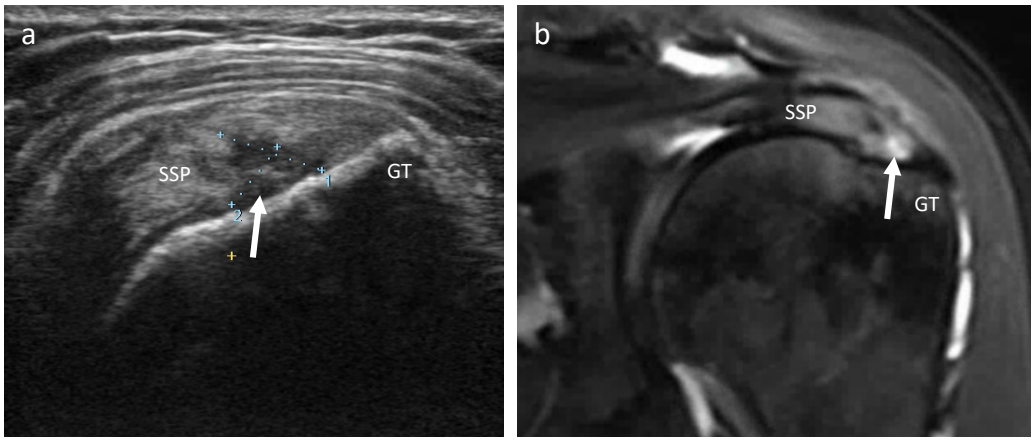

Figure 1. Partial-thickness supraspinatus tear. (a) Ultrasound (long axis) showed an articular side tear (arrow) of the supraspinatus tendon (SSP). (b) The oblique coronal T2-weighted fat-suppressed MRI showed the same configuration of the partial-thickness tear (arrow) of the supraspinatus tendon (SSP). Abbreviations: GT = greater tuberosity

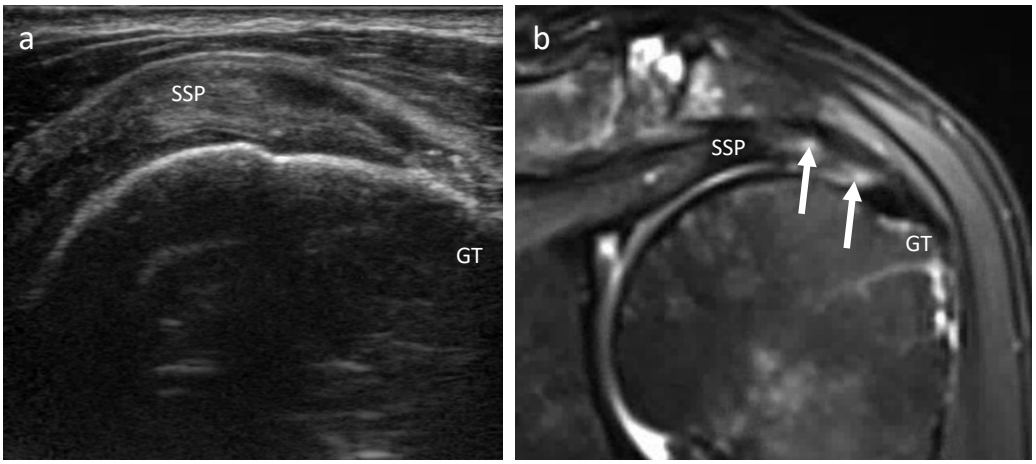

Figure 2. Ultrasonographic imaging underestimated partial-thickness supraspinatus tears. (a) Ultrasound (long axis) showed no tear of the supraspinatus tendon (SSP). (b) The oblique coronal T2-weighted fat-suppressed MRI showed an articular side tear (arrows) of the supraspinatus tendon (SSP). Abbreviations: GT = greater tuberosity

The critical weakness of US is that it is operator-dependent. That is, the result depends on the expertise of the sonographer. Yazigi et al. studied the accuracy of US using MRI as a reference standard and discovered that it has a low sensitivity (36%) but a high specificity (91.7%) for detecting all types of supraspinatus tears.[19] In the Yazigi study, the US operators were general radiologists, not musculoskeletal radiologists, so the sensitivity of ultrasound was low. In our study, the sensitivity was higher which could be the result of clinically relevant evaluation of the US operator.

One factor that may potentially have affected the sensitivity and specificity of US for detecting supraspinatus tears was that the US was performed by a physiatrist, not a musculoskeletal radiologist. However, the results showed good sensitivity, sufficient for screening supraspinatus tears in patients with shoulder pain. In the opinion of the authors, clinic-based US performed by a physiatrist has several advantages including real-time assessment, patients being more comfortable, being more cost-effective, requiring less time, and being more accessible, making it suitable for tertiary care hospitals. Additionally, US performed by a physiatrist can aid in the initial diagnosis and initial planning of treatment, especially in conservative treatment patients. In cases where severe pathology is found, the patient can then be referred to a specialist. MRI may also be performed to determine the exact location and size of the injury, aiding the planning of surgery.

There were some limitations of this study. First, the US findings were only compared with MRI but not with surgical findings, the gold standard, because most patients did not undergo surgery. Second, the US diagnosis, which is operator-dependent, was performed by only one physiatrist, so the results are specific to that examiner and cannot be generalized to other physiatrists. However, the results did show the accuracy of US done by a physiatrist after 1 month-training in musculoskeletal US, information which should be useful to physiatrists who are new to musculoskeletal US. Third, as it was a retrospective study, there was potential for a selection and information bias. We did not define the type of partial-thickness tears as articular, bursal, and intra-tendinous in both US and MRI. Additionally, the physiatrist who performed the ultrasound knew the patient's history and the results of clinical examination. Although those factors might have inflated the diagnostic accuracy of ultrasound, the US was performed in a real situation involving the clinical practice of a physiatrist. Lastly, the sample size was relatively small. A positive likelihood ratio of US for detecting all-type supraspinatus tears could not be calculated because there were no false positive cases. Future studies are needed which include a larger number of patients with shoulder pain and need to be conducted as prospective studies.

Conclusions

Shoulder US by a trained physiatrist showed high sensitivity and specificity for detecting supraspinatus tears diagnosed by MRI. Trained clinicians who are new to musculoskeletal ultrasound could use it in clinical-based evaluation of supraspinatus tendon tears for initial diagnosis and management.

Disclosure

The authors declare no conflicts of interest.

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