

# Accuracy of shoulder ultrasound examination for diagnosis of rotator cuff pathologies: a single-center retrospective study

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**BACKGROUND:** Shoulder pathologies need accurate diagnosis for best management and treatment provided to patients.

**OBJECTIVE:** Determine the diagnostic sensitivity, specificity and accuracy of shoulder ultrasonography (US).

**DESIGN:** Retrospective, analytical.

**SETTING:** Tertiary care center in Riyadh, Saudi Arabia.

**PATIENTS AND METHODS:** We included all shoulder exams performed between January 2010 and December 2016 that met the inclusion criteria. Data was collected retrospectively from the a picture archiving and communication system and patient records. The patients were evaluated using US for the presence of rotator cuff tears and classified into intact, full-thickness tear, partial-thickness tear, tendinosis, subacromial/subdeltoid bursitis and acromioclavicular joint degenerative changes. The US findings were correlated with the shoulder MRI study findings. The time interval between the US examination and MRI ranged from 0 to 180 days (6 months).

**MAIN OUTCOME MEASURES:** To compare the sensitivity, specificity and accuracy of shoulder US studies in the detection of rotator cuff pathologies in comparison to MRI findings.

**SAMPLE SIZE AND CHARACTERISTICS:** 86 (60 females, 26 male), mean age 53.7 years (range, 19-85).

**RESULTS:** The sensitivity, specificity and accuracy of US for the detection of full-thickness supraspinatus tears compared with those of MRI were 86%, 82% and 83%, respectively. The sensitivity, specificity and accuracy of US for the detection of partial-thickness supraspinatus tears compared with those of MRI were 38%, 70% and 58%, respectively. Overall PPV, NPV, sensitivity, specificity and accuracy of US for the detection of full-thickness tears compared with those of MRI were 35%, 97%, 78%, 83% and 83%, respectively. For partial-thickness tears, the overall PPV, NPV, sensitivity, specificity and accuracy of US compared with those of MRI were 51%, 60%, 51%, 60% and 56%, respectively.

**CONCLUSION:** Overall, US has high sensitivity, specificity and accuracy for the detection of full-thickness tears compared with the detection of partial-thickness tears.

**LIMITATIONS:** Small sample size and retrospective.

**CONFLICT OF INTEREST:** None.

The rotator cuff consists of a group of tendons and muscles attached to two bony structures: the humeral head and scapula. The function of these tendons and muscles is to stabilize the shoulder while allowing for free movement. The rotator cuff is composed of four muscles (the supraspinatus, infraspinatus, subscapularis and teres minor). These muscles are attached to the greater and lesser tuberosities of the humeral head by these tendons (the subscapularis, supraspinatus, and infraspinatus). There are many shoulder pathologies associated with shoulder pain and diagnosed by ultrasound (US) as well as magnetic resonance imaging (MRI), such as rotator cuff tears (RCTs), tendinosis, subdeltoid or subacromial bursitis, joint effusion, impingement and acromioclavicular joint degenerative changes.

The risk factors for RCTs increase with age.<sup>1,2</sup> Full-thickness RCTs are found in approximately 25% of individuals in their sixties, but affect more than 50% of people in their eighties.<sup>3</sup> Other risk factors are a history of trauma, dominant arm,<sup>1</sup> diabetes, smoking,<sup>2,4</sup> hypercholesterolemia and genetics.<sup>4</sup>

The rotator cuff can be visualized with non-invasive imaging techniques such as US<sup>5,6</sup> and MRI.<sup>6</sup> The demand for the diagnosis of rotator cuff tears and associated shoulder pathology is increasing. MRI can be costly and cannot be used in patients with pacemakers, metallic implants, or claustrophobia, while US is more readily available, less costly and most patients can tolerate the exam. US is also useful for performing a dynamic and functional evaluation of the shoulder. It has distinct advantages in that a dynamic assessment can be performed and contraction of the muscles can also be assessed.<sup>7,8</sup> Although US is frequently used to identify injuries or abnormalities, it is also used when performing injections into the knee, shoulder and hip. US guide injection provides significant additional benefits for the management of shoulder pain.<sup>9,10</sup>

US has been extensively validated and has achieved high levels of accuracy for detecting or ruling out full-thickness tears. A systematic review of the literature showed a pooled sensitivity and specificity of 0.95 and 0.96, respectively.<sup>11</sup> Sensitivity figures of 0.98 are reported when using a probe of 10 MHz or greater.<sup>12</sup> Several studies recently showed that US is as sensitive as MRI in the diagnosis of full-thickness tears, but less sensitive than MRI for detecting partial-thickness tears. Studies by Kulkarni and Chandrasekharan<sup>13</sup> and Saraya and El Bakry<sup>14</sup> showed high sensitivity and a specificity of 100% in the detection of full-thickness tears. For partial-thickness tears, US sensitivity and accuracy were 88% and 83%, respectively, in a study by

Saraya and El Bakry,<sup>14</sup> while a study by Kulkarni and Chandrasekharan<sup>13</sup> yielded an US sensitivity and specificity of 100% and 78%, respectively.

Another retrospective study by Chen and colleagues evaluated 36 patients with rheumatoid arthritis (RA) who had persistence shoulder pain.<sup>15</sup> They used arthroscopic findings as the gold standard to diagnose RCTs and all patients underwent US and MRI examinations before the arthroscopy. They found US to be a highly sensitive and accurate imaging modality for detecting full-thickness tears, but to have lower sensitivity in detecting partial-thickness tears. The sensitivity and accuracy of US for detecting full-thickness tears were 92.2% and 89%, respectively.<sup>15</sup> On the other hand, MRI sensitivity and accuracy were 96.4% and 90%, respectively.<sup>15</sup> For partial-thickness tears, the sensitivity and accuracy were 62.5% and 75%, respectively, for US and were 87.5% and 88%, respectively, for MRI.<sup>15</sup> The learning curve and experience increased with increasing use of US for the diagnosis of shoulder problems, which resulted in improved sensitivity and accuracy. Thus, when determining which test is the best to order, factors besides accuracy should be considered, including regional expertise with a test, the importance of ancillary clinical information (labral, capsular, ligamentous, or bony pathology), patient tolerance, and cost. A study published by Middleton and colleagues found that patients preferred US over MRI.<sup>16</sup> Therefore, patient perception of the test is also an important consideration.

## PATIENTS AND METHODS

Our retrospective study included all patients who underwent shoulder US and MRI at King Faisal Hospital and Research Center in Riyadh, Saudi Arabia, between January 2010 and December 2016.

Human ethical approval by the Research Ethics Committee and Research Advisory Council was obtained. Patients were evaluated using US for the presence of RCTs. Findings were classified into intact, full-thickness tear, partial-thickness tear, tendinosis, subacromial/subdeltoid bursitis and acromioclavicular joint degenerative changes, and correlated with MRI findings, which were considered the gold standard. Included in the study were any patient who underwent shoulder US followed by MRI in the period between January 2010 and December 2016 with a time interval between US and MRI ranging from 0-180 days (6 months), and had no surgical intervention between US and MRI evaluations. Patients were excluded from the study when no shoulder MRI was performed, when they underwent a shoulder MRI prior to US, when they had a limited US scan due to joint effusion or severe pain,

or when the time interval between MRI and US exceeded 6 months. Approximately 1000 patients were filtered. After patients who did not meet the criteria were excluded, 86 patients were included in the study. The clinical presentations and reasons for shoulder US showed that the majority of patients presented with shoulder pain (50%). However, many US studies had no clear relevant clinical history (30%). The remainder of the patients presented with a prior history of trauma, a decreased range of motion, osteoarthritis (OA), a history of prior arthroplasty, or pre-existing rheumatoid arthritis (RA). The US and MRI reporters were not blind to the patient history and examination findings.

All US examinations were performed by specialized musculoskeletal radiologists and/or musculoskeletal fellows, using a Philips IU22, EPICQ 7 with a 5-12 MHz linear array transducer and GE LOGIC9 with an ML6-15-D broad spectrum linear matrix array transducer. All tendons were examined and grayscale 2D US images were stored in a picture archiving and communication system. We followed the shoulder US protocol adapted by Beggs and colleagues.<sup>17</sup> All MRI examinations were performed with the following protocols: axial proton density fat saturation, coronal oblique T1 fast spin echo, coronal oblique T2 fast spin echo, sagittal oblique T2 fat saturation and coronal oblique T2 fat saturation. The MRI scanners used were the GE Discovery 3T, GE 1.5T, the Siemens Avanto 1.5T and the Siemens Trio 3T (<https://www.siemens-healthineers.com>).

SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for statistical analysis. The categorical variables are presented as counts and percentages. The accuracy of US and MRI (percentage of correct diagnosis) was calculated with 95% confidence interval (CI). MRI data and US data are crossed tabulated to report a positive predictive value (PPV), negative predictive value (NPV), sensitivity, and specificity. Logistic regression models were used to generate ROC curves.

## RESULTS

The 86 patients included in the study had a mean age of 53.7 years (range 19-85). Two cases had a normal rotator cuff as evaluated by both MRI and US: a 19-year-old male and a 36-year-old female. Rotator cuff pathology was noted in 59 (69%) female patients and 25 (29%) male patients. The most frequently affected side was the right side in 48 (56%) patients, while the left side was affected in 38 (44%) patients.

US evaluation of supraspinatus tendon revealed that it was intact in 47 (55%) patients intact, had a full-thickness tear in 7 (8%) patients). **Figure 1** shows numbers of patients with intact tendons or tendon injuries of the

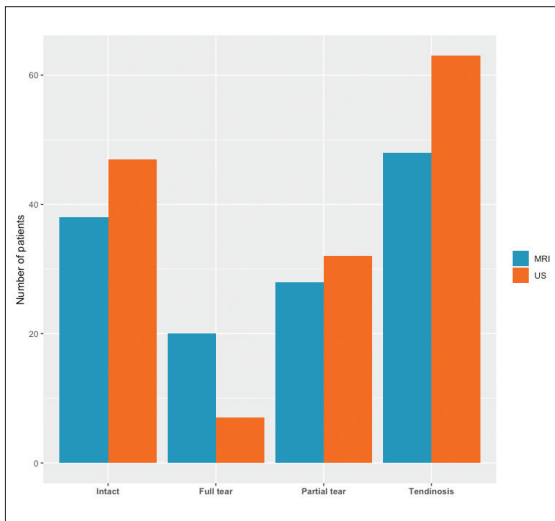
supraspinatus tendon by MRI and US. Some patients with an intact tendon had tendinosis. Both tendinosis and a tear occurred in 31 (36%) patients by US and 21 (24%) patients by MRI. Full thickness tears of the supraspinatus tendon are shown in **Supplementary Image 1** (US) and **2** (MRI) in the same patient, and a partial thickness tear is shown in **Supplementary Image 3** (US) and **4** (MRI). **Figures 2-4** show the numbers of infraspinatus, subscapularis and biceps tendon patients, respectively. Both tendinosis and a tear occurred in one patient with an infraspinatus tendon injury, in three patients with subscapularis tendon injuries, and in one patient with a biceps injury. **Figure 5** shows the numbers of patients with acromioclavicular joint degenerative changes and subdeltoid or subacromial bursitis.

Overall PPV, NPV, sensitivity, specificity and accuracy of US in the detection of full-thickness tears compared with those of MRI were 35%, 97%, 78%, 83% and 83%, respectively. **Supplementary Image 5** shows the ROC curves for US and MRI in the diagnosis of full-thickness tears. For partial-thickness tears the overall PPV, NPV, sensitivity, specificity and accuracy of US compared with those of MRI were 51%, 60%, 51%, 60% and 56%, respectively. **Supplementary Image 6** shows the ROC curves of the US and MRI in the diagnosis of partial-thickness tears. For tendinosis the overall PPV, NPV, sensitivity, specificity and accuracy of US compared with those of MRI were 84%, 25%, 74%, 38% and 67%, respectively. **Supplementary Image 7** shows the ROC curves of the US and MRI in the diagnosis of tendinosis.

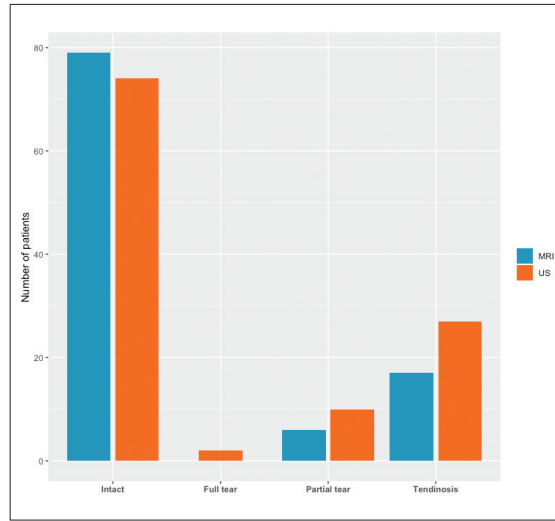
## DISCUSSION

In our study, the most commonly affected tendon was the supraspinatus followed by the infraspinatus and subscapularis. A total of 7 (8%) patients with full-thickness supraspinatus tears were identified on US and 20 (23%) patients were identified using MRI. US correctly identified 6 (7%) patients with a full-thickness tear as true positive (TP) and 1 (1%) patient as false negative (FN). Sensitivity, specificity and accuracy of US in the detection of full-thickness supraspinatus tears were 86%, 82% and 83% (95% CI=75 to 91%), respectively (**Table 1**). **Table 2** shows a comparison between our study and others.

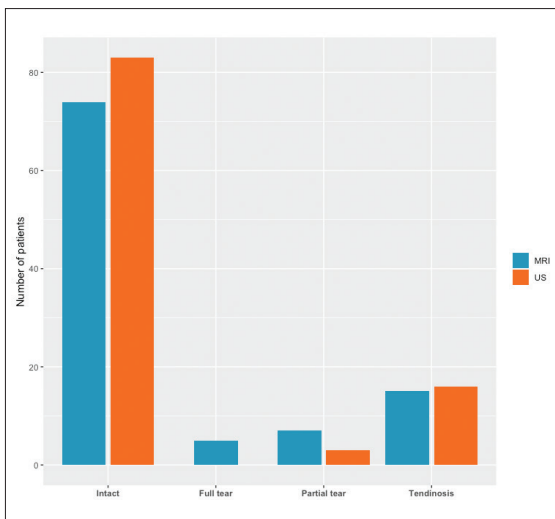
A total of 32 partial-thickness supraspinatus tears were identified on US and 28 (33%) were identified using MRI. US correctly identified 12 (14%) patients with partial-thickness tears as TP and 20 (23%) FN. The sensitivity, specificity and accuracy of US for detecting partial-thickness supraspinatus tears were 38%, 70% and 58% (95% CI, 48 to 69%), respectively (**Table 1**).



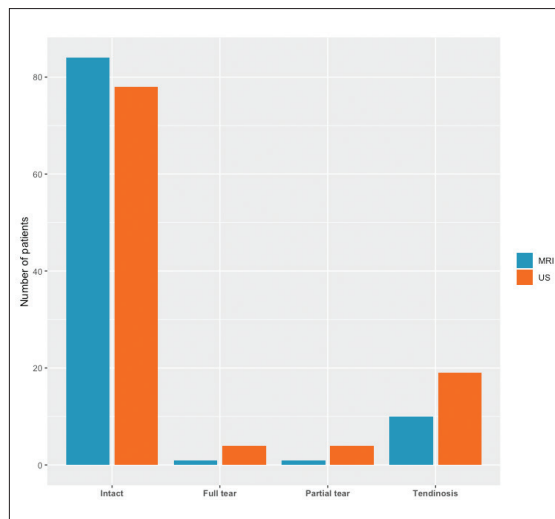
**Figure 1.** Number of patients with intact supraspinatus tendons, tears, and tendinosis.



**Figure 3.** Number of patients with intact subscapularis tendons, tears, and tendinosis.



**Figure 2.** Number of patients with intact infraspinatus tendons, tears, and tendinosis.



**Figure 4.** Number of patients with intact biceps tendons, tears, and tendinosis.

**Table 3** shows a comparison between our study and others. In our study the sensitivity of US was low for the detection of partial-thickness tears at approximately 38%, which is comparable to the sensitivity results reported by Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang<sup>18</sup> of approximately 43%.

For tendinosis, our study showed that the sensitivity of US for detecting supraspinatus tendinosis was 62% compared to MRI. This finding is comparable to the sensitivity results reported by Khanduri, Raja, Meha, Agrawal, Bhagat and Jaiswal<sup>19</sup> of approximately 63%. For the infraspinatus tendon, no patients with full-

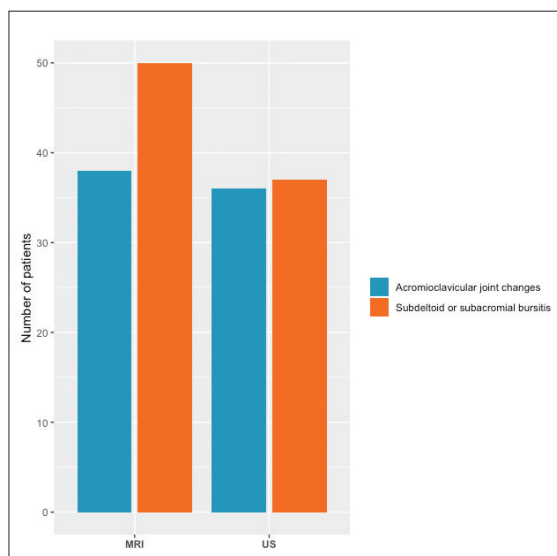
thickness tears were identified using US, but 5 (6%) identified using MRI. The number of patients who were negative for tears as identified by US (86 [100%] on US and 81 [94%] on MRI) resulted in a high specificity of US detection of approximately 94% (**Table 1**). Our results were considerably higher than the study done by Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang<sup>18</sup> (**Table 2**). The sensitivity of US for the detection of partial-thickness infraspinatus tears was low, at approximately 33% (**Table 3**).

For the subscapularis tendon, the specificity of US for the detection of full-thickness tears was 100% and

**Table 1.** Comparison of supraspinatus, infraspinatus, subscapularis, biceps tendons, acromioclavicular joint and subdeltoid/subacromial bursitis findings on US with MRI.

	PPV	NPV	Sensitivity	Specificity	Accuracy	95% Confidence interval (CI)
<b>Supraspinatus tendon</b>						
Intact	74%	60%	60%	74%	66%	56-76%
FT	30%	99%	86%	82%	83%	75-91%
PT	43%	66%	38%	70%	58%	48-69%
Tendinosis	81%	37%	62%	61%	62%	51-72%
<b>Infraspinatus</b>						
Intact	97%	8%	87%	33%	85%	77-92%
FT	N/A	100%	N/A	94%	N/A	N/A
PT	14%	98%	33%	93%	91%	85-97%
Tendinosis	40%	86%	38%	87%	78%	69-87%
<b>Subscapularis</b>						
Intact	87%	29%	93%	17%	83%	75-91%
FT	N/A	99%	N/A	100%	N/A	N/A
PT	17%	89%	10%	93%	84%	76-92%
Tendinosis	41%	71%	26%	83%	65%	55-75%
<b>Biceps</b>						
Intact	93%	100%	100%	25%	93%	88-98%
FT	100%	97%	25%	100%	97%	93-100%
PT	100%	97%	25%	100%	97%	93-100%
Tendinosis	60%	83%	32%	94%	80%	72-89%
ACJ degenerative changes	61%	73%	64%	70%	67%	55-77%
Subdeltoid or subacromial bursitis	52%	69%	70%	51%	59%	49-70%

**Figure 5.** Number of patients with degenerative changes in the acromioclavicular joint and subdeltoid or subacromial bursitis.



higher than has been reported in other studies (**Table 2**). The US sensitivity in the detection of partial-thickness tears, on the other hand, was only 10%, which is low (**Table 3**).

The overall PPV, NPV, sensitivity, specificity and accuracy of US for the detection of full-thickness tears compared with those of MRI were 35%, 97%, 78%, 83% and 83%, respectively (**Table 4**). For partial-thickness tears, the overall PPV, NPV, sensitivity, specificity and accuracy of US compared with those of MRI were 51%, 60%, 51%, 60% and 56%, respectively (**Table 5**). For tendinosis, the overall PPV, NPV, sensitivity, specificity and accuracy of US compared with those of MRI were 84%, 25%, 74%, 38% and 67%, respectively (**Table 6**).

**Tables 4, 5 and 6** compare the overall PPV, NPV, sen-

**Table 2.** Sensitivity, specificity and accuracy of US for the detection of full-thickness tears compared with MRI.

	Sensitivity	Specificity	Accuracy
<b>Supraspinatus</b>			
Our study	86%	82%	83%
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	100%	91%	-
Kulkarni and Chandrasekharan <sup>13</sup>	100%	100%	100%
Khanduri, Raja, Meha, Agrawal, Bhagat and Jaiswal <sup>19</sup>	95%	91%	92%
<b>Infraspinatus</b>			
Our study	N/A	94%	N/A
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	100%	92%	-
<b>Subscapularis</b>			
Our study	N/A	100%	N/A
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	50%	95%	-

**Table 3.** Sensitivity, specificity and accuracy of US for the detection of partial-thickness tears compared with MRI.

	Sensitivity	Specificity	Accuracy
<b>Supraspinatus</b>			
Our study	38%	70%	58%
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	43%	100%	-
Kulkarni and Chandrasekharan <sup>13</sup>	100%	78%	84%
Khanduri, Raja, Meha, Agrawal, Bhagat And Jaiswal <sup>19</sup>	60%	98%	80%
<b>Infraspinatus</b>			
Our study	33%	93%	91%
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	70%	94%	-
<b>Subscapularis</b>			
Our study	10%	93%	84%
Fischer, Weber, Neubecker, Bruckner, Tanner and Zeifang <sup>18</sup>	57%	87%	-

**Table 4.** Overall sensitivity, specificity and accuracy of US for the detection of full-thickness tears compared with MRI.

	PPV	NPV	Sensitivity	Specificity	Accuracy	Gold Standard
Our study	35%	97%	78%	83%	83%	MRI
Saraya and El Bakry <sup>14</sup>	-	-	100%	100%	-	MRI
Rutten, Spaargaren, van Loon, de Waal Malefijt, Kiemeney and Jager <sup>20</sup>	88%	98%	95%	93%	94%	Surgery
Ottenheijm, Jansen, Staal, van den Bruel, Weijers, de Bie <sup>11</sup>	-	-	95%	96%	-	
Chen, Lan, Lai, Chen, Chen and Chen <sup>15</sup>	-	-	92%	-	89%	Arthroscopy
Fotiadou, Vlychou, Papadopoulos, Karataglis, Palladas and Fezoulidis <sup>21</sup>	-	-	-	-	98%	Surgery
Ok, Kim, Kim and Yoo <sup>22</sup>	-	-	80%	-	82%	Arthroscopy
Milosavljevic, Elvin and Rahme <sup>23</sup>	91%	100%	100%	91%	95%	Arthroscopy
Labanauskaite <sup>24</sup>	100%	82%	80%	100%	-	Arthroscopy

**Table 5.** Overall sensitivity, specificity and accuracy of US for the detection of partial-thickness tears compared with MRI.

	PPV	NPV	Sensitivity	Specificity	Accuracy	Gold Standard
Our study	51%	60%	51%	60%	56%	MRI
Saraya and El Bakry <sup>14</sup>	94%	80%	88%	89%	83%	MRI
Rutten, Spaargaren, van Loon, de Waal Malefijt, Kiemeney and Jager <sup>20</sup>	40%	98%	89%	80%	81%	Surgery
Ottenheijm, Jansen, Staal, van den Bruel, Weijers, de Bie <sup>11</sup>	-	-	72%	93%	-	
Chen, Lan, Lai, Chen, Chen and Chen <sup>15</sup>	-	-	63%	-	75%	Arthroscopy
Fotiadou, Vlychou, Papadopoulos, Karataglis, Palladas and Fezoulidis <sup>21</sup>	-	-	-	-	87%	Surgery
Ok, Kim, Kim and Yoo <sup>22</sup>	-	-	46%	-	45%	Arthroscopy
Milosavljevic, Elvin and Rahme <sup>23</sup>	86%	96%	80%	98%	95%	Arthroscopy
Labanauskaite <sup>24</sup>	85%	75%	79%	82%	-	Arthroscopy

**Table 6.** Overall sensitivity, specificity and accuracy of US for the detection of tendinosis compared with MRI.

	PPV	NPV	Sensitivity	Specificity	Accuracy	Gold Standard
Our study	84%	25%	74%	38%	67%	MRI
Ottenheijm, Jansen, Staal, van den Bruel, Weijers, de Bie <sup>11</sup>			67%-93%	88%-100%		

sitivity, specificity and accuracy of US for the detection of full-thickness tears, partial-thickness tears and tendinosis in our study compared with several other studies. In conclusion, US is a readily available, less costly imaging modality and most patients can tolerate the exam. US is also useful for performing a dynamic, functional evaluation of the shoulder. US has distinct advantages in that a dynamic assessment of muscle contraction can also be performed. US can also be used as a screening modality for the evaluation of suspected RCTs. Overall, US has a high sensitivity, specificity and accuracy for the detection of full-thickness tears compared with the detection of partial-thickness tears. The supraspinatus

tendon was the most commonly affected tendon. US is sensitive and specific for the detection of full-thickness tears of the supraspinatus tendon but less sensitive for partial-thickness tears. For the other tendons, US has high specificity for the detection of both full-thickness and partial-thickness tears.

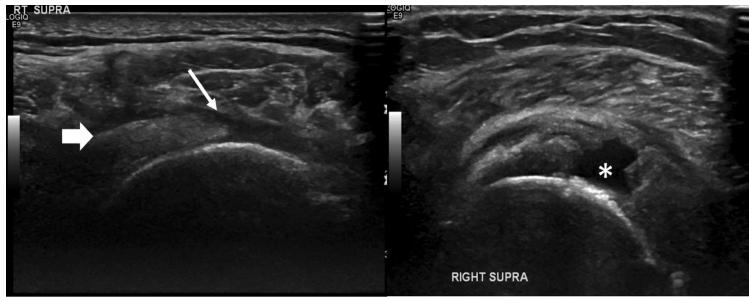
In conclusion, more studies with a larger cohort of patients should be performed specifically for the assessment of the infraspinatus and subscapularis tendons in order to be able to correctly measure sensitivity, specificity and accuracy of US for evaluation of these tendons and to correlate the findings between MRI and US.

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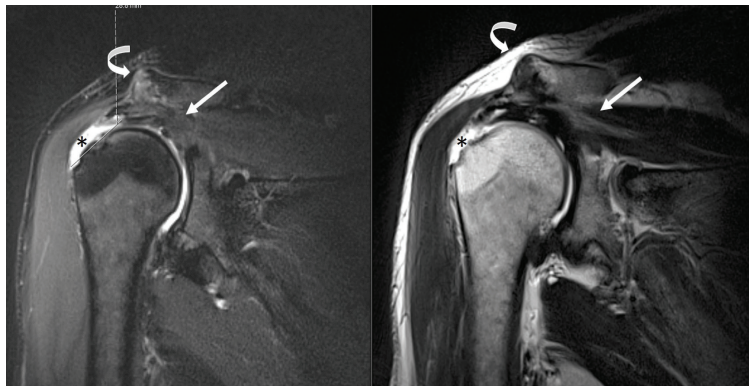
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**SUPPLEMENTS**



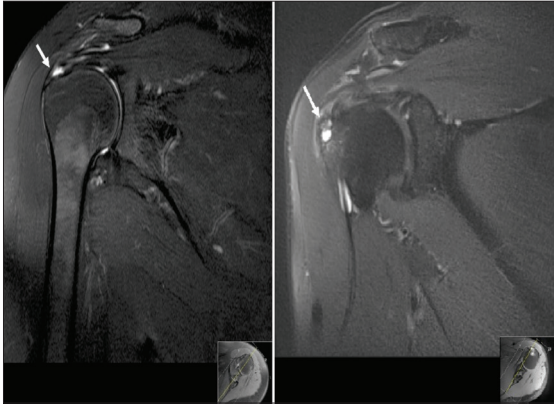
**Supplementary Image 1.** LEFT. Longitudinal ultrasound shows full thickness midfiber tear of supraspinatus tendon with tendon discontinuity (arrow). Gap is filled with anechoic fluid (\*) with fibers retracted medially (→). RIGHT. Transverse ultrasound of the same patient showing full thickness midfiber tear of supraspinatus tendon. Anterior fibers and posterior fibers remain intact.



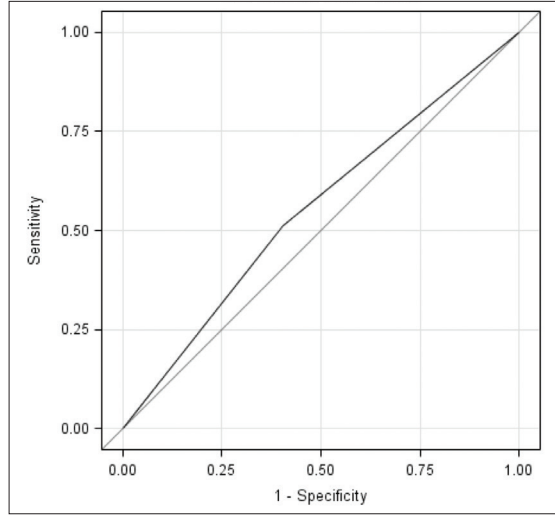
**Supplementary Image 2.** Coronal oblique Fat-suppressed proton density fat-spin-echo MRI of the same patient showing a complete tear of the supraspinatus tendon, which is minimally retracted medially (arrow), uncovering the humeral head with subacromial bursal fluid collection (\*). Note the degenerative joint disease of the acromioclavicular joint with osteophytes projecting inferiorly (curved arrow). Right: Coronal oblique fat-suppressed proton density fat-spin-echo. Left: Coronal oblique T2.



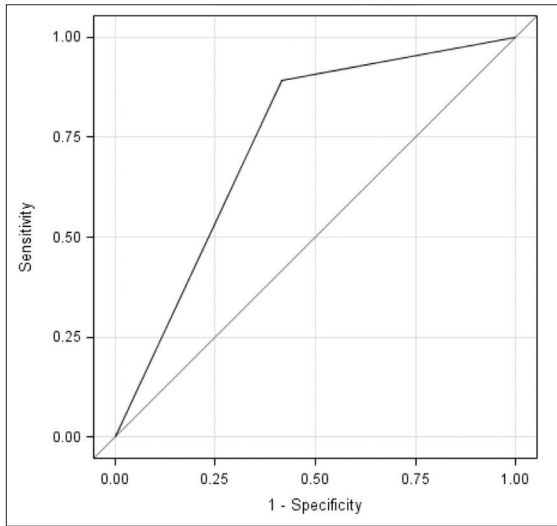
**Supplementary Image 3.** Longitudinal view of the supraspinatus tendon showing discrete irregular hypoechoic focus at the articular margin (arrow), consistent with partial thickness tendon tear. Note the intact superficial fibers (\*)



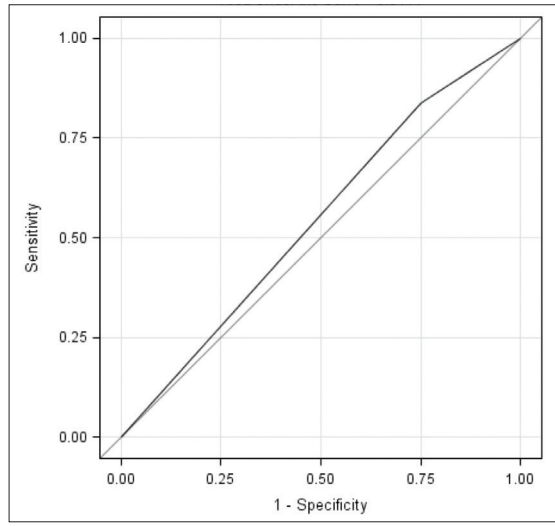
**Supplementary Image 4.** Coronal oblique Fat-suppressed proton density fat-spin-echo MRI showing the broad footprint of the normal insertion of the supraspinatus tendon onto the greater tuberosity where it is interrupted with fluid (arrow), which indicates a partial articular-sided cuff tear.



**Supplementary Image 8.** ROC curve for the diagnosis of partial-thickness tears by US and MRI (area under the curve=0.5543).



**Supplementary Image 7.** ROC curve for diagnosis of full-thickness tears by US and MRI (area under the curve=0.7376).



**Supplementary Image 9.** ROC curve for diagnosis of tendinosis by US and MRI (area under the curve=0.5444).