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A Retrospective Comparative Study of Ultrasound and MRI in the Diagnosis of Supraspinatus Tendon Tears at a Medical Center in Taiwan

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Objective: To evaluate the diagnostic accuracy of ultrasound (US) in comparison with magnetic resonance imaging (MRI), which is the gold standard for detecting full- and partial-thickness supraspinatus (SS) tendon tears at our general practice.

Methods: From January 2015 to January 2016, 107 patients suffering from shoulder pain underwent both US and MRI of the shoulder at a medical center to identify their shoulder pathology, and were included in this work. The US was performed by a physiatrist at a US laboratory, and the US findings for the SS tendon were classified as normal, tendinosis (calcific/ non-calcific), a partial-thickness tear, or a full-thickness tear. MRI results were reported by a radiologist. The sensitivity, specificity, and accuracy of the sonographic assessment were determined by comparing them with the MRI findings. Correlations between the US and MRI results were analyzed using Cohen's kappa coefficient.

Results: The results showed that the kappa coefficient of association was 0.80 for SS full-thickness tendon tears. This indicated that the agreement between US and MRI for the diagnosis of SS full-thickness tendon tears was excellent. Moreover, the accuracy of US in detecting full-thickness tears of the SS tendon, if we take MRI to be the gold standard, was 0.91, with a sensitivity of 0.91, and a specificity of 0.90. However, when using US to detect partial-thickness tears of the SS tendon, the accuracy and sensitivity were low-0.73 and 0.30 respectively-although there was high specificity (0.92).

Conclusions: US was highly accurate for detecting SS full-thickness tendon tears in daily general practice, but was less sensitive and accurate for detecting SS partial-thickness tendon tears. Further large-scale studies are needed. (Tw J Phys Med Rehabil 2016; 44(4): 187 - 199)

Key Words: rotator cuff tears; shoulder; magnetic resonance imaging (MRI); ultrasound

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INTRODUCTION

Full- or partial-thickness supraspinatus (SS) tendon tears are a common cause of shoulder pain and disability.\cite{1-3} Treatment strategies depend on the clinical symptoms as well as the size of the lesion.\cite{4} Acute full-thickness tears with a lesion size greater than 1-1.5 cm and young patients with full-thickness tears should be considered to be candidates for surgery, whereas partial-thickness tears are candidates for more conservative treatment.\cite{5} Thus, it is important to differentiate partial- and full-thickness tears of the SS tendon to determine treatment pathways.

Currently, magnetic resonance imaging (MRI) is the reference standard for the diagnosis of SS tendon lesions. However, it is expensive, time consuming, and not always easily available.\cite{6} Moreover, MRI has other disadvantages, like the fact that it is contraindicated in patients with implanted medical devices or claustrophobia.\cite{7} Recently, ultrasound (US) has become increasingly popular for the diagnosis of soft-tissue lesions such as SS tendon tears.\cite{8} US is less expensive and also provides real-time dynamic scans. The technological evolution of high-resolution ultrasound scanners has facilitated substantial improvements in the quality of images and the accuracy of SS tendon tear evaluation.\cite{9}

Although there is good support for the use of US to diagnose full-thickness tears of the SS tendon, there is controversy regarding its use to diagnose partial-thickness tears.\cite{10,11} In addition, most published studies are prospective, with the advantages of being randomized, well controlled, having standardized procedures, and conducted by experienced operators. However, such studies are also subject to the disadvantages of limited numbers of subjects, not reflecting real clinical status, and being specific to certain special conditions. Although retrospective studies may have biases, unreliable operators, and nonstandardized procedures, they are more appropriate for evaluating the conditions in daily clinical practice.

This study aimed to explore the diagnostic accuracy of US in comparison with MRI, which is the gold standard for detecting full-and partial-thickness supraspinatus tendon tears, at our general practice.

MATERIALS AND METHODS

From January 2015 to January 2016, 2930 subjects from the rehabilitation department of a university hospital who were undergoing sonographic examination for shoulder pain were selected. A total of 107 patients who subsequently underwent MRI were included in this retrospective comparative study (58 women, 49 men; mean age: 56.6 years; days between US and MRI: 38 days). Patients who underwent surgery during the period between the US and MRI were excluded.

All sonographic examinations were performed by physiatrists with 2–22 years experience in musculoskeletal sonography. A 14-MHz bandwidth linear-array transducer was used (Acuson S2000 system; Siemens Ultrasound, Mountain View, CA, USA, or Xario SSA-660A; Toshiba, Tokyo, Japan). To reveal the SS tendon, the patient was positioned in the modified Crass position. The MRI was performed in a 1.5 T GE Signa Excite scanner, with a shoulder coil on the affected shoulder and the arm in an externally rotated position.

On the US, the criterion for diagnosis of an SS tendon tear was a hypoechoic area that persisted in at least two different planes. A full-thickness tear (Figure 1) was defined as a continuous hypoechoic or anechoic cleft from the bursal space to the articular surface, loss of the normal SS tendon with exposure of a bare area of bone and cartilage, or a complete absence of the tendon.\cite{8,12} A partial-thickness tear (Figure 2) was diagnosed when there was a focal hypoechoic or anechoic defect in the tendon, involving either the bursal surface, articular surface, or the intratendinous substance, manifested in two perpendicular planes.\cite{13}

On MRI, the criteria for an SS tendon tear were increased signal intensity in association with a discontinuity or irregularity of the tendon on T2-weighted and fat-suppressed PD-weighted images. A full-thickness tear (Figure 3) was characterized by a continuous tendon gap connecting the bursal space with the articular surface. A partial-thickness tear (Figure 4) was characterized by a high signal intensity within the tendon substance, without retraction of the tendon.\cite{6,14}

The data were collected and a descriptive statistical
Diagnostic Accuracy of Ultrasound in Supraspinatus Tendon Tears

Analysis was carried out to evaluate the sensitivity, specificity, and accuracy of US for detecting SS tendon damage, and to estimate the correlation between it and the MRI findings, which served as a standard reference. The agreement between the two methods was assessed using the kappa coefficient.

**RESULTS**

MRI revealed 44 (41.1%) full-thickness SS tendon tears, 33 (30.8%) partial-thickness SS tendon tears, 11 (10.3%) cases of tendinosis (three cases of calcific tendinosis, eight of non-calcific tendinosis), and 19 (17.8%) healthy tendons. US showed 46 (43.0%) full-thickness SS tendon tears, 16 (15.0%) partial-thickness SS tendon tears, 27 (25.2%) cases of tendinosis (15 of calcific tendinosis, 12 of non-calcific tendinosis), and 18 (16.8%) healthy tendons.

On comparing the US findings with the MRI findings, 40 cases (37.4%) of full-thickness SS tendon tears and 10 cases (9.3%) of partial-thickness SS tendon tears were similarly classified by both US and MRI (Table 1). Compared with MRI, for full-thickness SS tendon tears, US showed a sensitivity of 0.91 and specificity of 0.90, and for partial-thickness SS tendon tears, a sensitivity of 0.30 and a specificity of 0.92. The accuracy of US for diagnosing full- and partial-thickness SS tendon tears was 90.0% and 72.0%, respectively. The agreement between the two methods was assessed using the kappa coefficient, which was 0.80 for full-thickness but only 0.26 for partial-thickness SS tendon tears (Table 2). Thirty-three partial-thickness SS tendon tears were diagnosed by MRI, but only 10 of these cases (30.3%) were identically diagnosed by US.

We compared both methods for diagnosing full-thickness tears of the SS tendon to the operative findings. Diagnostic matches were found for 30/34 (88.2%) MRI diagnoses (Table 3.1) and 29/34 (85.3%) US diagnoses (Table 3.2).

**DISCUSSION**

We found that US is a reliable tool for detecting full-thickness tears of the SS tendon. A recent meta-analysis\[15\] showed that overall estimates of the sensitivity and specificity of diagnosing such tears were 0.86–0.94 and 0.91–0.96, respectively. These findings are similar to those of the present study, which found a sensitivity of 0.91 and specificity of 0.90 for US when compared to MRI as the gold standard. This confirms the high accuracy (0.91) of US for diagnosing full-thickness SS tendon tears. The kappa coefficient was 0.80, indicating strong agreement between the two methods in the diagnosis of such tears. US is thus a good diagnostic tool for detecting complete SS tendon tears, especially for patients who have contraindications for MRI.

However, US exhibited low accuracy and sensitivity, 0.73 and 0.30 respectively, for detecting partial-thickness tears to the SS tendon, although it had a high specificity (0.92). Meta-analyses have also reported high specificity (0.87–0.94) and relatively low sensitivity (0.54–0.86) for diagnosing partial-thickness tears of the SS tendon with US\[15,16\]. This inconsistency between MRI and US in the evaluation of these tears has also been reported in previous works\[6,17-19\]. Several likely reasons for misdiagnosis have been identified. First, small partial-thickness tears can be missed, whereas large focal defects of the tendon mimic full-thickness tears\[8\]. Waldt et al. stated that diagnosis of small partial-thickness tears is challenging because of difficulties in differentiating between fiber tearing, tendinitis, synovitis changes, and superficial fraying at tendon margins\[8\]. Other errors occur because of difficulties distinguishing extensive partial-thickness tears from full-thickness tears using sonography. Errors also occur due to the substantial loss of cuff substance and compressibility in the few remaining fibers and the transducer\[21\]. Teefey et al. claimed that focal defects of more than 50% of the cuff substance can mimic full-thickness tears by virtue of their compressibility\[8\].

In addition, old partial-thickness tears to the SS tendon may mimic tendinopathy, as the margins of chronic degeneration in the tear are poorly defined and demonstrate a heterogeneous appearance on US\[22\]. Central tears (interstitial/intra-substance tears) are also difficult to assess because they may be confused with enthesopathy or deep surface lesions, owing to their proximity to the cephalic articular cartilage\[23,24\].

Our study revealed similar specificity (0.92), but much lower sensitivity (0.30), compared to previous...
This might be attributable to greater inter-operator variability in the diagnosis of partial-thickness SS tendon tears (Table 4). Our work was performed by 15 operators, who had variable experience and diagnostic criteria. Interpretations of the US findings differed between operators, especially for the secondary US signs of rotator cuff tears.

The importance of secondary US signs (greater tuberosity cortical irregularity, cartilage interface sign, joint fluid, subacromial-subdeltoid bursal fluid, and herniation of the deltoid muscle) as indicators of rotator cuff tears has been debated in previous studies. For the diagnosis of SS tendon tears, greater tuberosity cortical irregularity had the greatest sensitivity (0.69) and the highest accuracy (0.72); however, relatively low sensitivity (0.42–0.47) and accuracy (0.52–0.57) were observed for diagnoses based on joint or bursa fluid. The cartilage interface sign had the greatest specificity (100%) and the highest positive predictive values (100%), but low sensitivity (0.19). A hyperechoic interface between the hyaline cartilage and the overlying rotator cuff can be depicted normally, although Jacobson et al. found that this sign is subjective.

There was an interesting but non-conclusive finding in our work: 60% of the patients diagnosed with SS calcific tendinosis by US were shown to have partial-thickness tears to the SS by MRI. In total, 15 (45.4%) of the partial-thickness tendon tears diagnosed by MRI were misclassified as tendinosis by US (nine [27.3%] as calcific tendinosis, and six [18.1%] as non-calcific tendinosis). Merolla et al. found that there is a 23–28% probability of the coexistence of calcific tendinosis and rotator cuff tears. The integrity of the rotator cuff is associated with the texture of the calcific deposit. In our study, most patients (62.5%) diagnosed with calcific tendinosis in the partial-thickness tendon tear group had well-defined margins and no acoustic shadow. There was a significant trend (p = 0.086) of calcific patterns with well-defined margins and no acoustic shadow yielding a higher likelihood of partial-thickness tears (Table 5, Figure 5), but further studies are needed to confirm this pattern.

There were several limitations in this work. First, the number of surgically established cases was small, especially for the partial-thickness tear group. Second, there may have been some technical errors, such as machine (or probe) and operator errors, pertaining to both sonographic and MRI examinations, in this retrospective study.

**CONCLUSION**

This study showed that the accuracy of US for detecting full-thickness SS tendon tears in daily general practice was high. However, it was less sensitive and accurate for diagnosing partial-thickness SS tendon tears. Further studies are required to clarify the relatively low diagnostic test accuracy of US for partial-thickness SS tendon tears, and to elucidate the relationship between calcific deposits and the integrity of the SS tendon.
Figure 1: Ultrasonographic imaging of full-thickness supraspinatus (SS) tendon tear US of a patient showing full thickness tear of SS (white arrow).
(A) transverse view (B) longitudinal view
Hum, humerus
Figure 2: Ultrasonographic imaging of partial-thickness SS tendon tear.
US of a patient showing bursa surface partial thickness tear of SS (white arrow).
(A) transverse view (B) longitudinal view
Figure 3: Magnetic resonance imaging of full-thickness SS tendon tear
(A,B) MRI oblique coronal T2 weighted image (A), sagittal fat suppressed PD-weighted image (B) showing high signal in the full thickness of the supraspinatus tendon. (white arrow)

Figure 4: Magnetic resonance imaging of partial-thickness SS tendon tear
(A,B) MRI oblique coronal T2 weighted image (A) sagittal fat suppressed PD-weighted image (B) showing a high signal in the bursa surface of the supraspinatus tendon with torn tendon fibers. (white arrow)
Table 1. Comparison of supraspinatus tendon pathology in US with MRI.

<table>
<thead>
<tr>
<th>Ultrasound/MRI (SS findings)</th>
<th>Normal</th>
<th>Tendinosis</th>
<th>Partial thickness tears</th>
<th>Full thickness tears</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>calcific</td>
<td>Non calcific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Tendinosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcific</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Non calcific</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Partial thickness tears</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Full thickness tears</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>3</td>
<td>8</td>
<td>33</td>
<td>44</td>
</tr>
</tbody>
</table>

* One humeral head micro-fracture was misdiagnosed as calcific tendinosis by US.

The accuracy of sonographic examination -
- Full thickness tear: Sensitivity 40/44 = 0.91, specificity 57/63 = 0.90, accuracy 97/107 = 0.91
- Partial thickness tear: Sensitivity 10/33 = 0.30, specificity 68/74 = 0.92, accuracy 78/107 = 0.73

Table 2. Correlation of the US findings for full and partial thickness tears with MRI.

<table>
<thead>
<tr>
<th>N=107</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
<th>Kappa coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS Full thickness tears</td>
<td>0.91</td>
<td>0.90</td>
<td>0.91</td>
<td>0.80</td>
</tr>
<tr>
<td>SS Partial thickness tears</td>
<td>0.3</td>
<td>0.92</td>
<td>0.73</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 3.1 Comparison of supraspinatus tendon tear-type in MRI with surgical findings.

<table>
<thead>
<tr>
<th>Surgical/MRI</th>
<th>No</th>
<th>Partial</th>
<th>Full</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Partial</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Full</td>
<td>0</td>
<td>2</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>total</td>
<td>3</td>
<td>2</td>
<td>29</td>
<td>34</td>
</tr>
</tbody>
</table>

MRI findings were consistent with surgical findings: 30/34= 88.2%.

Table 3.2 Comparison of supraspinatus tendon tear-type in US with surgical findings.

<table>
<thead>
<tr>
<th>Surgical/US</th>
<th>No</th>
<th>Partial</th>
<th>Full</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Partial</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Full</td>
<td>0</td>
<td>2</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>total</td>
<td>3</td>
<td>2</td>
<td>29</td>
<td>34</td>
</tr>
</tbody>
</table>

US findings were consistent with surgical findings: 29/34= 85.3%.
Table 4. Diagnostic accuracy between ultrasound operators

<table>
<thead>
<tr>
<th>Attending physician</th>
<th>Years Of experience</th>
<th>Case number</th>
<th>Full-thickness tear Dx Accuracy</th>
<th>Partial-thickness tear Dx Accuracy</th>
<th>All Dx Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>22</td>
<td>10</td>
<td>1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>3</td>
<td>NA</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>C</td>
<td>16</td>
<td>7</td>
<td>0.85</td>
<td>0.85</td>
<td>0.71</td>
</tr>
<tr>
<td>D</td>
<td>7</td>
<td>22</td>
<td>0.86</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>7</td>
<td>0.86</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>5</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>G</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>H</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>I</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>J</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
<td>9</td>
<td>15</td>
<td>0.93</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>L</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>M</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>N</td>
<td>2</td>
<td>1</td>
<td>NA</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>O</td>
<td>7</td>
<td>8</td>
<td>0.875</td>
<td>*0.5</td>
<td>*0.375</td>
</tr>
</tbody>
</table>

Table 5. Correlation of calcium deposits pattern with SS integrity

<table>
<thead>
<tr>
<th>Margin &amp; Acoustic shadow</th>
<th>SS integrity</th>
<th>Partial tear</th>
<th>No tear</th>
<th>Total</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well/AS+</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.825</td>
<td></td>
</tr>
<tr>
<td>Well/AS-</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>0.086*</td>
<td></td>
</tr>
<tr>
<td>ill/AS+</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.231</td>
<td></td>
</tr>
<tr>
<td>ill/AS-</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>0.334</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>6</td>
<td>14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: well/ill = well/ill-defined margin; AS= Acoustic shadow.

Patient with calcific tendinosis in partial-thickness tear group had well-defined margin without acoustic shadow: 5/8=0.625.

* There is a borderline significant trend (p=0.086).
Figure 5: Calcific deposits pattern.
(A) well defined margin with acoustic shadow. (white arrow). (B) ill defined margin without acoustic shadow. (white arrow). (C) well defined margin without acoustic shadow. (white arrow).
REFERENCES

超音波及磁振造影於診斷棘上肌斷裂之回溯性比較研究

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研究目的：以磁振造影為標準診斷來評估超音波檢查對於棘上肌斷裂之診斷準確性。

研究方法：此研究分析 107 位罹患肩痛且接受過肩關節超音波及磁振造影檢查之病人；軟組織超音波由一群醫學中心復健科醫師所執行，將棘上肌之超音波影像區分為正常、肌腱病變(鈣化/非鈣化)、部分斷裂及全厚度斷裂。磁振造影結果則由影像科醫師負責判讀。比較超音波與磁振造影於診斷棘上肌斷裂之敏感性、特異性、診斷準確性，更進一步利用 kappa 統計量來評估兩檢查之相關性。

結果：超音波及磁振造影對於棘上肌全厚度斷裂的診斷有高度相關性(Kappa coefficient = 0.8)，超音波對於棘上肌全厚度斷裂之診斷準確率、敏感性及特異性分別為 0.91、0.91、0.90；但超音波對於偵測棘上肌部分斷裂的診斷準確率為 0.73、敏感性也有 0.3，雖然其特異性高達 0.92。

結論：超音波檢查對於診斷棘上肌斷裂有相當高的診斷準確性，但針對棘上肌部分斷裂的敏感性及準確率則較差，未來仍需要更多研究釐清相關原因來提升棘上肌部分斷裂之診斷準確率。 (台灣復健醫誌 2016；44(4)：187 - 199)

關鍵詞：旋轉肌腱破裂(rotator cuff tears)、肩(shoulder)、磁振造影(MRI)、超音波(ultrasound)

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