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Research Article

Diagnostic accuracy of ultrasound in subscapularis tendon abnormalities and the importance of operator experience

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ABSTRACT

Objective: This study aimed to investigate the reasons behind the compliance, diagnostic success, and failure of ultrasound (US) examinations of two radiologists with reference to magnetic resonance imaging (MRI) in the abnormalities of subscapularis (SSC) tendon, including tendinosis.

Methods: One less experienced radiologist (operator-1) and one senior radiologist, experienced in the musculoskeletal US (operator-2), performed the shoulder US on 78 patients (mean age: 53.18±10.89 [22-73] years), who had undergone MRI for routine reasons except malignancy, within 1-4 weeks of MRI. Tendinopathy, partial (PT), or full-thickness (FT) tears were recorded in the subscapularis. The thickness of the anterior and lateral soft tissues in the shoulder girdle was measured by MRI. The inter-operator agreement on the US results, the US-MRI compliance for each operator, and the relationship between the US-MRI compliance and tissue thickness were investigated.

Results: The inter-operator agreement on the US findings was moderate. The US-MRI compliance was fair for operator-1, but substantial for operator-2. The circumferential soft tissue thickness and US-MRI compliance were not correlated ($p>0.05$). The interobserver agreement in US was moderate (K: 0.415). The US-MRI compliance was fair for operator-1 (K: 0.344) and substantial for operator-2 (K: 0.616). The accuracy rates for the differentiation of normal tendon, tendinosis, PT, and FT were 59%, 75%, 72%, and 100%, respectively, for operator-1 and 87%, 83%, 85%, and 100%, respectively, for operator-2. However, the respective sensitivity of operator-1 was 46%, 19%, 44%, and 100%; and operator-2 was 91%, 67%, 82%, and 100%. The diagnostic performance of operator-1 was lower, except for FT.

Conclusion: The thickness of the surrounding tissue does not affect the US results. The differentiation between tendinosis and PT tear is difficult (more prominent in less experienced user); however, because this would not change the treatment choice, shoulder US is recommended after basic training in subscapularis pathologies.

Level of Evidence: Level II, Diagnostic study

Pathologies of the subscapularis (SSC) tendon, one of the four tendons forming the shoulder girdle, are generally overlooked, with the available research mostly focusing on the supraspinatus (SSP) tendon (1, 2). SSC tendon tears are very difficult to detect in a clinical examination. Despite extensive maneuvers, the examination has very limited accuracy, and muscle function may be compensated by the other muscles of the shoulder girdle (3). Concomitant SSC tears have been reported in 24%-69% of massive rotator cuff tears (4). Eighty percent of SSC tears are accompanied by SSP tears (5). Naimark et al. reported the coexistence rate of SSC and SSP tears to be 67% (3). The prevalence of SSC tears ranges from 29% to 37% in cadaver studies (6), and 5% to 27% in clinical studies (7, 8). This wide discrepancy is due to the incomplete visualization of the SSC tendon in some cases of open surgery and arthroscopy (9).

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Magnetic resonance imaging (MRI) provides anatomical cross-sectional images of shoulder abnormalities. However, global health expenditures are increasing, and the cost of MRI is much higher than ultrasound (US). Patients with Parkinson's disease or those with shoulder pain cannot remain stable during screening, and claustrophobics are usually unable to undergo MRI because it involves being in an enclosed space. Furthermore, MRI appointments are given much later than US worldwide. In addition, shoulder US has become more popular because it is effective in revealing rotator cuff abnormalities and is cost-effective, time-efficient, and performed in real-time. US achieves immediate results through a bilateral evaluation and obtaining clinical information by speaking with the patient.

The SSC tendon is rarely the subject of isolated studies, and research on the rotator cuff often focuses on tears (1-3, 5, 10). In addition, we usually observe that tendinosis is often left outside the imaging area (11, 12). The radiologic and arthroscopic evaluation of the SSC tendon involves more challenges, and thus, requires availability of technology and experience (2, 10). Therefore, in the present study, we aimed to investigate the reasons behind the inter-operator agreement in US, and diagnostic success or failure of one senior and one less experienced radiologist in relation to the abnormalities of the SSC tendon including tendinosis, by taking the MRI findings as a reference.

Materials and Methods

Prior to the study, approval was obtained from the local ethics committee of Süleyman Demirel University, School of Medicine (72867572.050.01-43818, 07.03.2017). Furthermore, the examination was explained to patients and informed consent was obtained. Patients who had undergone shoulder MRI for any reason other than neoplasia were randomly assigned to US appointments by the other researchers (except the two radiologists) within 1-4 weeks of the MRI procedure.

Shoulder US was performed by the two radiologists at different times of the same day and the findings were recorded. The first radiologist (the less experienced operator) was a radiology trainee in his fifth year, with 4 months of experience in musculoskeletal radiology and 50-cases shoulder US training. The second radiologist (the senior operator) had 15 years of experience in musculoskeletal radiology-ultrasonography.

HIGHLIGHTS

- The amount of muscle and subcutaneous fatty tissue at the shoulder girdle does not have any negative influence on modern diagnostic tools such as US scanners.
- If US training is performed on a certain number of patients, the users may differentiate between shoulder lesions requiring or nor not requiring a surgical intervention.
- Distinction between tendinosis and partial rupture it is not important as the treatment is same.

Shoulder MRI was used as the reference method. The shoulder MRI's of the subjects were evaluated by a radiologist with 10 years of experience. This radiologist did not evaluate the US results. MRI was performed using a Magnetom Avanto 1.5 T device (Siemens, Erlangen, Germany) with an 8-channel shoulder array. The proton-weighted axial and sagittal T1- and T2-weighted coronal sequences were obtained. For the US procedure, an Aplio 500 device (Toshiba, Otawara, Japan) and high-resolution 18 mHz and 11 mHz multifrequency linear probes were used. US examinations were performed using the current standardized shoulder US protocol.

The number of cases was 78, of whom 45 (57.7%) were females and 33 (42.3%) were males. The patients with congenital anomalies of the shoulder girdle, any rheumatologic diseases, history of shoulder girdle surgery, any cancer diagnosis, and those under the age of 18 years were excluded from the study.

In this study, both the SSP and SSC tendons were evaluated, but the specific focus was on the latter. The reason behind the inclusion of the SSP tendon in this assessment was to reveal the differences between the two radiologists regarding their evaluation of the relatively easily visualized SSP and more challenging SSC, and the possible reasons behind these differences.

The thickness of the subcutaneous fat tissue surrounding the shoulder girdle of the patients, the muscle thickness, and the total thickness of the two were measured in two regions using the axial MRI sections. Both measurements were performed at the point where the biceps tendon groove could be best visualized; the first was on the lateral aspect, perpendicular to the center of the glenoid cavity and the second was on the anterior aspect, 45° to this line (Figure 1). The relationship between the thickness values and the US-MRI compliance of the operators was investigated.

The presence of normal tendon, tendinosis (tendinopathy), and PT and FT tears was recorded for both SSP and SCC tendons with MRI and US. Partial tears were not classified according to the types (bursal, articular, and intrasubstance) because the number of cases were not sufficient for statistical analysis.

For the US assessment, tendinopathy was defined as the loss of fibrillar echoes and hypoechoic appearance, PT tear as the presence of fluid or hypertrophic bursal tissue in the tendon defect area, and FT tear as a defect that extend to the articular surface from the bursal side. In MRI, tendinopathy was defined as the presence of a lesion indicated by increased

signal intensity on short time echo (TE) sequences such as proton density (PD), and signal intensity lower than the fluid on long TE sequences such as T2. A PT tear was represented by a defect in the articular, bursal side, or intrasubstance of the tendon, and by increased signals in this area on T1- and T2-weighted images. An FT tear was indicated by a defect extending from the bursal side to the articular surface (Figure 2). The size of the tears was not measured on MRI or US. Lesions of other parts of the shoulder joint were also not recorded because they were outside of the study scope.

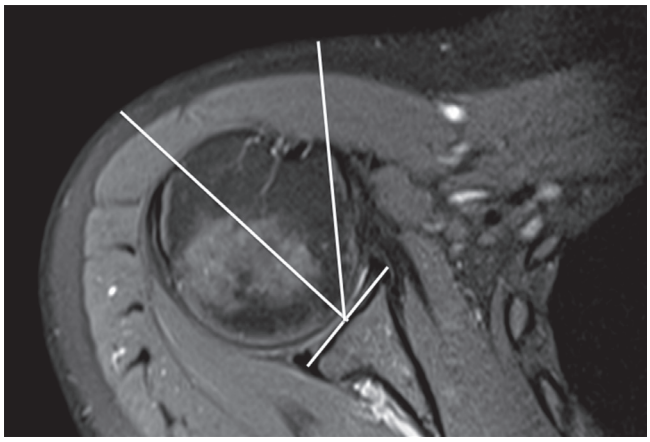

Figure 1. Standardized measurement method for soft tissue surrounding the rotator cuff. Fat-suppressed, proton-weighted axial sequence. Both measurements were performed at the point where the biceps tendon groove was best selected; the first was on the lateral aspect, perpendicular to the center of the glenoid cavity and the second was on the anterior aspect, 45° to this line. The subcutaneous fat tissue was measured as the distance from the skin surface to the muscle surface, and the muscle thickness as the distance from the muscle surface to the bone surface

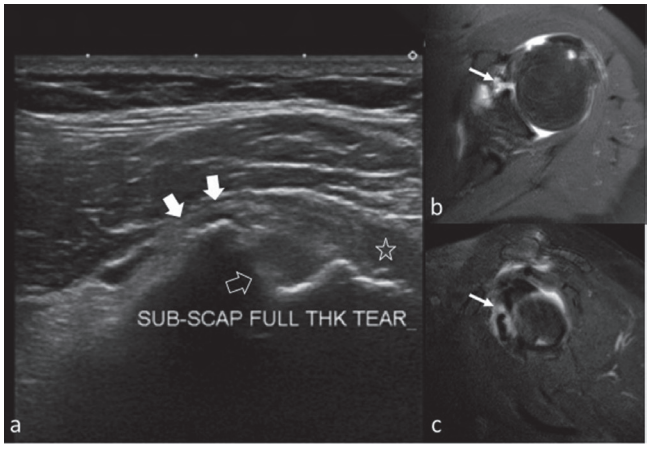

Figure 2. a-c. A case with full-thickness tear in the subscapularis tendon. (a) Long axis view of the subscapularis tendon on US. The full-thickness tear area on the superior part of the tendon and synovial hypertrophic filling this area is shown (thick arrows); this part of the tendon is close to the biceps tendon. Hypertrophic degeneration is seen on the biceps tendon girdle (open arrow). On the other side of the biceps tendon, the supraspinatus tendon is seen (asterisk). (b, c) Full-thickness tear of the superior part of the subscapularis tendon are seen on the axial and coronal plane fat-suppressed proton-weighted MRI sequences (thin arrows). The hyperintense effusion accompanies the subacromial-subdeltoid bursa and the shoulder joint

Statistical analysis

Descriptive statistics on continuous data were obtained as mean and standard deviation values. The t-test was used for comparisons. The consistency of the measurements was evaluated using the Kappa coefficient (K). Statistical Package for the Social Sciences version 11.5 (SPSS Inc.; Chicago, IL, USA) program was used for all statistical analysis, accepting $p<0.05$ as the limit of statistical significance.

The US-MRI compliance of each operator was evaluated using the Landis and Koch classification (13). The results were interpreted as no concordance if the kappa value was 0, slight agreement if 0.0-0.20, fair agreement if 0.21-0.40, moderate agreement if 0.41-0.60, substantial agreement if 0.61-0.80, and almost perfect agreement if 0.81-1.00.

Results

Patients' mean age was 53.18 ± 10.89 (22-73) years. Table 1 presents measurements of soft tissue thickness of the shoulder girdle for all patients. The comparison of US findings with the reference MRI findings for the two operators is given in Table 2.

Regarding US results, the operators had moderate agreement on SSC tendon pathologies (K: 0.415) and almost perfect agreement for the SSP tendon (K: 0.821). The US-MRI compliance of the less experienced operator was fair for the SSC tendon (K: 0.344) and substantial for the SSP tendon (K: 0.656). For the senior radiologist, the compliance level for both tendons was substantial (K: 0.616 for the SSC tendon, 0.716 for the SSP tendon) (Table 3). There was no correlation between the soft tissue thickness in the shoulder girdle and the US-MRI compliance of the operators ($p>0.05$).

Table 4 presents the sensitivity, specificity, and accuracy rates of the two operators for the evaluation of the abnormalities in the SSC and SSP tendons.

Table 1. The mean soft tissue thickness of the shoulder girdle (mm)

Parameter	Anterior	Lateral
Total thickness	24.3±7.9	21.43±6.82
Fat thickness	10.8±6.8	9.59±5.04
Muscle thickness	13.5±3.8	11.83±3.63

Table 2. The US findings related to the subscapular and supraspinatus tendons, as reported by the less experienced and senior operators, and the corresponding MRI results

Subscapular		**Ultrasound**			
Normal	**Tendinosis**	**Partial tear**	**Full-thickness tear**	**MRI reference**	
20 (16)	1 (2)	(3)		21	Normal
14 (4)	4 (14)	3 (3)		21	Tendinosis
17 (1)	2 (4)	15 (28)	(1)	34	Partial tear
			2 (2)	2	Full-thickness tear
Supraspinatus		**Ultrasound**			
Normal	**Tendinosis**	**Partial tear**	**Full-thickness tear**	**MRI reference**	
7 (7)				7	Normal
12 (5)	5 (10)	2 (4)		19	Tendinosis
5 (5)	(1)	26 (25)		31	Partial tear
		1	20 (21)	21	Full-thickness tear

MRI: magnetic resonance imaging
The numbers in the table represent the number of cases (n). The data belonging to the senior operator are given in parentheses

Table 3. The inter-operator agreement in US and the US-MRI compliance of each operator

Inter-operator agreement on US findings		
	K-Se	**p**
Subscapular	0.415 / 0.067	0.001
Supraspinatus	0.821 / 0.049	0.001
The US-MRI compliance of the less experienced operator		
	K-Se	**p**
Subscapular	0.344 / 0.067	0.001
Supraspinatus	0.656 / 0.056	0.001
The US-MRI compliance of the senior operator		
	K-Se	**p**
Subscapular	0.616 / 0.064	0.001
Supraspinatus	0.716 / 0.055	0.001

K: kappa coefficient; Se: standard error; US: ultrasound; MRI: magnetic resonance imaging

Discussion

Studies evaluating the SSC tendon independently are few in the radiology and orthopedic literature (2, 10). Image resolution problems caused by the lack of experienced US operators and the deep tendon location result in insufficient data for the evaluation of the tendon characteristics such as the multi-pennate structure and anatomical orientation (14).

The data-results of the current study can be used to identify the related problems and seek possible solutions. The substantial agreement between the US and MRI findings of the senior operator offered a good constant that facilitated the discussion of the possible reasons behind the errors of the less experienced operator and the challenges arising from the anatomical characteristics of the tendon.

First, one of the limitations of the use of US in the musculoskeletal system is the thickness of subcutaneous fat tissue or the deep localization of the target tissue (tendon, ligament muscle, etc.) (15). However, the current study revealed no correlation between the soft tissue thickness in the shoulder girdle and the US-MRI compliance of the operators. In other words, the average thickness of the tissue covering the tendon (subcutaneous fat and muscle tissue) did not affect the results of US. This can be considered a good outcome because this disadvantage of US is slowly being overcome by the advances in technology. Furthermore, in obese patients, the MRI procedure is difficult to perform because the imaging table has a weight limit and the patient may not fit into the MRI gantry. In addition, patients with pain often cannot remain immobile during the scan. For the evaluation of these cases, US is the frontline examination method and linear-high frequency transducers are available for use. High frequency means low penetration. However, with the advances in probe technology, multifrequency probes now allow the selection of a lower frequency when examining deep tissues. Furthermore, the use of an appropriate focus, selection of a narrow field of view, and software that increases image resolution, varying from one device to another, can be optimized for assessment of obese patients.

Table 4. The diagnosis success analysis of the two operators for the subscapular and supraspinatus tendon

	Less Experienced Operator			Senior Operator		
Subscapular	**Sensitivity**	**Specificity**	**Accuracy**	**Sensitivity**	**Specificity**	**Accuracy**
Normal	46	95	59	91	76	87
Tendinosis	19	95	75	67	89	83
Partial tear	44	93	72	82	86	85
Full-thickness tear	100	100	100	100	100	100
Supraspinatus	**Less Experienced Operator**			**Senior Operator**		
Normal	100	76	78	100	86	87
Tendinosis	26	100	82	53	98	87
Partial tear	84	94	89	81	91	87
Full-thickness tear	95	100	100	100	100	100

The second disadvantage of the US examination is that it is an operator-dependent imaging method and has a long learning curve. In this study, the less experienced operator had lower sensitivity in evaluating normal SSC tendons and those with tendinopathy or a PT tear (46%, 19%, and 44%, respectively). The sensitivity of the same operator for tendinosis in the SSP tendon was 26%, which is significantly lower than that of the senior operator. Similarly, the senior operator had the lowest sensitivity in the diagnosis of tendinosis, 67% for the SSC tendon and 53% for the SSP tendon. In the US reports of both the operators, one of the common errors was misdiagnosis of tendinosis as PT tear or vice versa. This was explained by the vague borders of chronic degeneration causing difficulty in differentiating between tendinosis and PT tear (16). In acute tears, the effusion in the defect area eliminates this problem (11). Since the patient group comprised chronic cases, the senior operator was also not fully adequate in making such a differentiation.

Studies investigating tendinosis of the rotator cuff by US are relatively limited compared with those on tears. In fact, separation of tendinosis from a PT tear does not have any practical benefits considering that both are treated using non-surgical options (17). Two different studies evaluating US and MRI showed that this problem was common for both the methods (11, 12); this limitation of US is also present in MRI and such a differentiation does not alter the treatment option for the patients (17). In contrast, in another study that compared arthroscopy and MRI, it was reported that the overall sensitivity was increased from 78% to 100% when the small SSC tears were removed from the analysis as they did not require surgical treatment (2). It is also known that for rotator cuff tears left untreated, spontaneous recovery or reduction in size is highly unlikely (18). These cases can continue to be followed up by US, and in patients who are not responsive to treatment with conservative methods, arthrography or arthroscopy can be considered if MRI is not able to clarify the clinical state (2, 19, 20).

Due to the less experienced operator's difficulty in assessing the SSC tendon, the inter-operator agreement on US was only at a moderate level. Interestingly, the US-MRI compliance of the less experienced practitioner was higher for the SSP tendon and is classified as substantial. Furthermore, the concordance of the US results of the two operators was almost perfect for the SSP tendon. The higher success of the less experienced operator in the SSP tendon increased the inter-operator agreement. As explained above, this can be attributed to the simple morphology and orientation of the SSP tendon. Radiologists usually take less time to get familiarized with the SSP tendon compared with the SSC tendon. The characteristics of the SSC tendon require a longer learning curve not only with US but also with MRI and arthroscopy (2, 10).

The PT and FT tears in the SSC tendon were reported as 67% and 86%, respectively by Farin et al. (21), and varied between 90% and 98% according to Fotiadou et al. (16). In the current study, the PT and FT tears in the SSC tendon were diagnosed at 82% and 100%, respectively, for the senior operator and 44% and 100%, respectively, for the less experienced operator. In all three studies, US was performed by radiologists. Therefore, the reasons for the differences in the results may be the capability of the device used and the level of experience of the operator. In another recent comparative US-MRI study, US was performed by an experienced orthopedic surgeon with a sensitivity of 57% and 50%, respectively (22), which are generally lower compared with the findings of the studies conducted with radiologists.

Shoulder US cannot be performed in many academic and private centers because of the lack of a radiologist with mus-

culoskeletal US experience. In addition to the challenges of US related to the anatomy of the shoulder girdle and the difficulty of pathological evaluation, there are other factors that further complicate this process; for example, the clinician may want to see the abnormalities in an image but a printed version may not available, or the clinician may be unfamiliar with US images. In fact, tears can be easily followed up with US (17). However, in the US examination of the SSC tendon, the shoulder should be in external rotation. If this range of motion is not sufficiently provided, visualization may not be adequate. In such cases, MRI should be preferred if the patient can remain stationary throughout the scan.

Selection of MRI as a reference method can be considered a limitation of this study. However, a meta-analysis showed that MRI had the best sensitivity and comparable specificity in PT and FT tears of the rotator cuff (23). This information led us to accept MRI as the gold standard. Another limitation may be related to the lack of comparing tear sizes as an independent criterion; however, we did not undertake this comparison because of the difficulty in comparing small-size tears.

In conclusion, the US examination of the SSC tendon is particularly challenging for less experienced radiologists. However, this difficulty usually occurs at the point of separation between tendinosis and PT tears; in most cases, this inadequacy will not change the treatment modality. Therefore, it is recommended that because of its many known and abovementioned advantages, shoulder US should be performed by radiologists after receiving a predefined level of training to evaluate SSC pathologies, as with other rotator cuff abnormalities.

Ethics Committee Approval: Ethics committee approval was received for this study from the Local Ethics Committee of the Süleyman Demirel University, School of Medicine (72867572.050.01-43818, 07.03.2017).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

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