Diagnostic Accuracy of High Resolution Ultrasound in Communicating Rotator Cuff Tears

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Background/Objective: High resolution ultrasound is performed in the investigation of rotator cuff pathology. However, there are various reports in the literature regarding the diagnostic accuracy of ultrasound. The purpose of our study was to compare the diagnostic accuracy of ultrasound with multislice computed tomography arthrography (CT arthrography).

Patients and Methods: We prospectively studied sixty-four consecutive patients with rotator cuff pathology diagnosed by ultrasound (35 men and 29 women; age range, 35-75) who underwent preoperative multislice CT arthrography of the shoulder from February 2006 to January 2008. Full-thickness and communicating partial-thickness tears of the supraspinatus, infraspinatus, subscapularis tendons as well as the abnormalities of the long head of the biceps tendon were assessed.

Results: The right shoulder was involved in 44 patients. The supraspinatus tendon was the most frequently involved either by full-thickness (n=50) or partial-thickness (n=29) tears. Ultrasound correctly identified full-thickness rotator cuff tears in 84 % of cases with a good positive predictive value (83%). The sensitivity and specificity of ultrasound in the detection of partial-thickness tears were 76% and 46%, respectively. These percentages significantly increased with the presence of joint effusion (77% vs 70%) and joint and subacromial/subdeltoid bursal effusion (80% vs 67%).

Conclusion: Ultrasound allows an accurate diagnosis of full-thickness tears. The diagnostic performance of ultrasound in the assessment of partial-thickness tears increases when a joint effusion or double effusion is present.

Keywords: Shoulder, Rotator Cuff, Ultrasound, CT Arthrography, Injury

Introduction

Rotator cuff tears are common causes of shoulder pain. Among these lesions, tears that communicate with the articular cavity are widely predominant, including full-thickness tears, articular-surface partial-thickness tears, and communicating intratendinous tears. High resolution ultrasound is known to be a non-invasive, powerful and accurate method in the assessment of rotator cuff abnormalities.[1-2] However, reports in the literature on the diagnostic accuracy of ultrasound vary widely.[3-6] The purpose of our study was to compare the diagnostic accuracy of ultrasound with multislice computed tomography arthrography (CT arthrography). To our knowledge (based on pubmed internet), this comparison has never been previously reported in the literature.

Patients and Methods

From February 2006 to January 2008, sixty-four consecutive patients were referred to the radiology department for both ultrasound and pre-operative multislice CT arthrography of the shoulder to investigate rotator cuff injuries. For this reason, obtaining the informed consent from the patients and ethics committee approval was not judged necessary.

In all patients (35 male and 29 female; age range, 35-75 years; mean age, 56 years),

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ultrasonographic examinations were performed by one of three radiologists having at least 5 years of experience of musculoskeletal imaging. These radiologists were not aware of the clinical and radiographic details, and the one who performed CT arthrography was not aware of the ultrasonographic findings (double blind test). The US study was accomplished using 7-12 MHz or 11-15 MHz linear transducers (Philips HD 11).

The sonographic examinations were all standardized and included an assessment of full-thickness and communicating partial thickness tears of the supraspinatus, infraspinatus and subscapularis tendons, as well as long biceps abnormalities (tear, subluxation and dislocation). The mean time interval between US and CT arthrography was 105 days.

CT arthrography was performed using a Philips 6-slice CT with a 1 mm slice thickness after intra-articular contrast injection under fluoroscopic guidance. Anterior approach to the shoulder joint was used, followed by intra-articular injection of 8 ml of Hexabrix.

Statistical analysis of the obtained data was made using SPSS 15.0, which included a comparison of percentages of independent series (Chi-square test) and a comparison between the diagnostic value of ultrasound and CT arthrography by calculating the sensitivity (Se), specificity (Sp), positive predictive value (PPV) and negative predictive value (NPV). The significance threshold was considered at 0.05.

The agreement between the two methods was assessed using kappa coefficient. (0.20 and lower, no or poor agreement; 0. 21-0.4, low agreement; 0.41-0.60, moderate agreement; 0.61-0.80, good agreement; 0.81 and higher, very good agreement).

Results

The highest frequency for rotator cuff tear was observed in patients aged between 50 and 59 years. The right shoulder was involved in 44 patients (68%) and the left shoulder in 20 patients (32%). No complications occurred during contrast injection.

CT arthrography showed full-thickness tear of at least one tendon in 51 patients (80%) and a communicating partial-thickness tear of at least one tendon in 41 patients (64%).

The supraspinatus tendon was involved in 55 patients (86%), the infraspinatus tendon in 41 patients (64%) and the subscapularis tendon in 24 patients (38%).

The supraspinatus tendon was most frequently involved either by full-thickness (n=50) or partial-thickness (n=29) tears, followed by the infraspinatus tendon (22 full-thickness and 29 partial-thickness tears) and subscapularis tendon (15 full-thickness and 14 partial-thickness tears).

Among partial-thickness tears, articular-surface partial-thickness tears were observed in seven patients (11%) and communicating intratendinous cleavages in 40 patients (63%) (Fig. 1).

Among these 64 patients, the biceps tendon was involved in 16 cases, including six internal dislocations, five tears, two subluxations, two cleavages, and one thin appearance of the biceps tendon without tear (Fig. 2).

Table 1 summarizes the dignostic efficacy indices

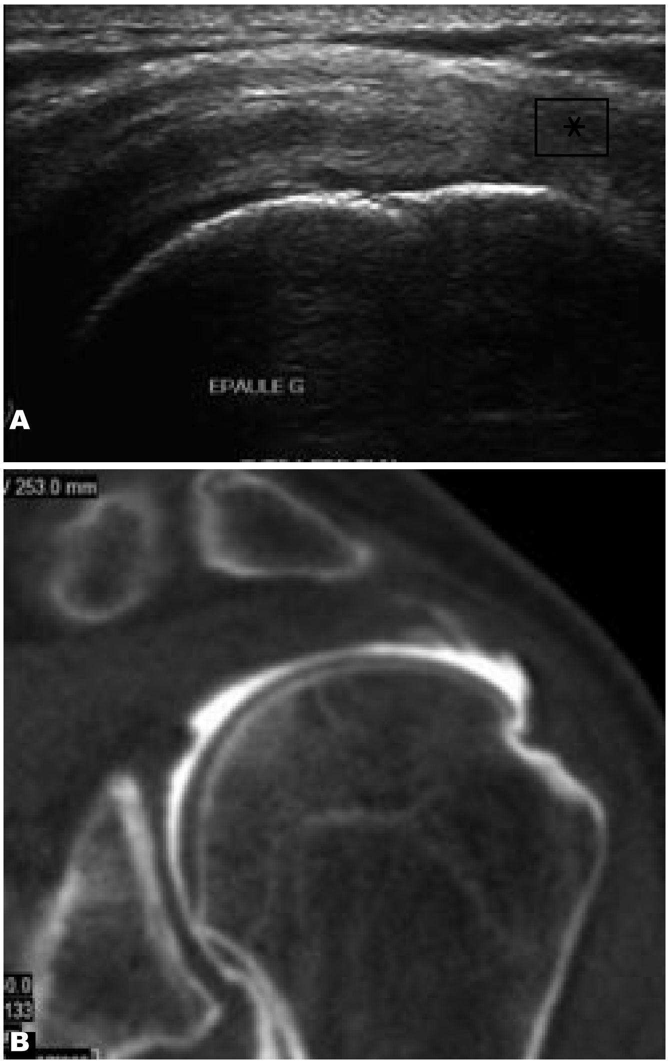

Fig. 1. A 70-year-old man with partial-thickness tears of the supraspinatus tendon.
A. Coronal ultrasonographic view of the supraspinatus tendon: Hypoechoic appearance of the distal tendon end (*).
B. Coronal CT arthrography view of the supraspinatus tendon shows an articular-surface partial-tear.

of US versus CT arthrography for full-thickness and communicating partial-thickness tears of each tendon. Table 2 compares the diagnostic accuracy of US according to the presence or absence of joint effusion alone or joint and subacromial/subdeltoid bursal effusion.

In three cases, an articular-surface partial-thickness tear of the supraspinatus tendon diagnosed by ultrasound was shown to be a full-thickness tear on CT arthrography, and in three cases, full-thickness tears of the supraspinatus tendon diagnosed on ultrasound were found to be only articular- surface partial-thickness tears on CT arthrography (Fig. 3).

In two cases, CT arthrography showed a full-thickness tear of the supraspinatus tendon while the ultrasonographic appearance was perfectly normal (Fig. 4).

In six cases, ultrasound diagnosed a full-thickness tear of the supraspinatus tendon but CT arthrography was normal (Fig. 5).

Discussion

High resolution US is a non-invasive low-cost technique which allows a good exploration of all rotator cuff tendons including the articular surface, the bursal surface and intratendinous abnormalities. The

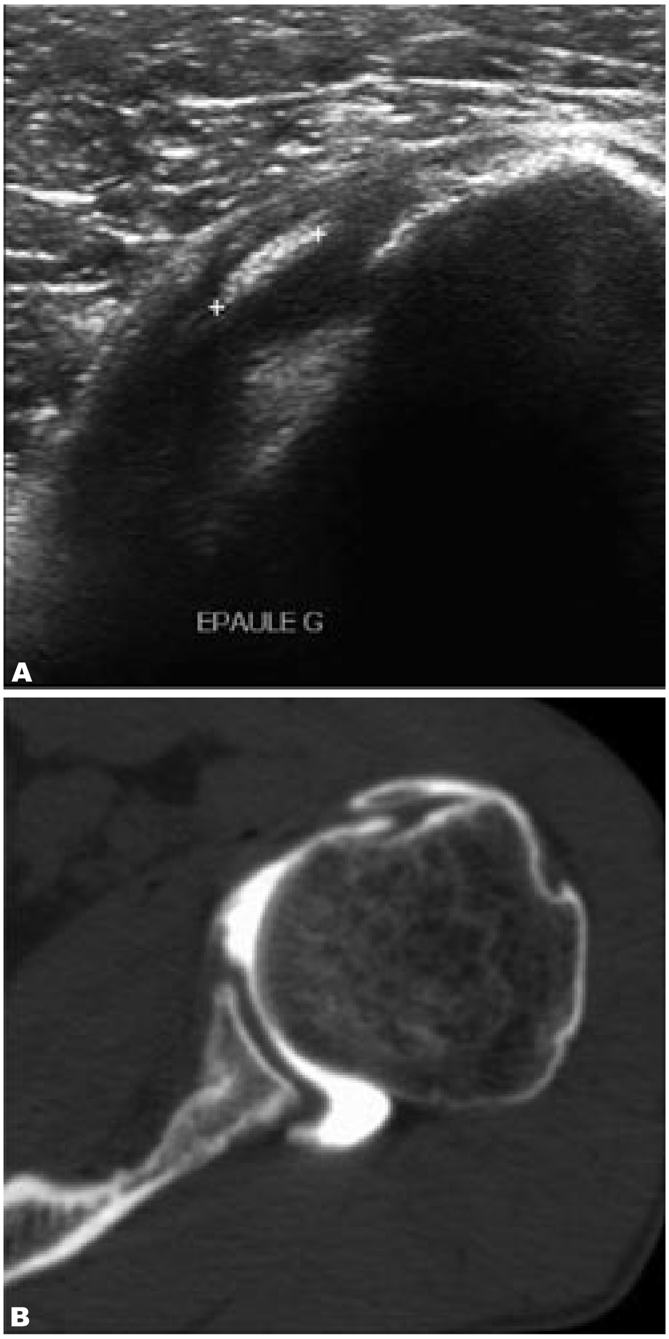

Fig. 2. A 40-year-old woman with internal dislocation of the biceps within a subscapularis intratendinous tear.
A. Transversal view of the biceps tendon on high resolution ultrasound.
B. CT arthrography confirmed the diagnosis.

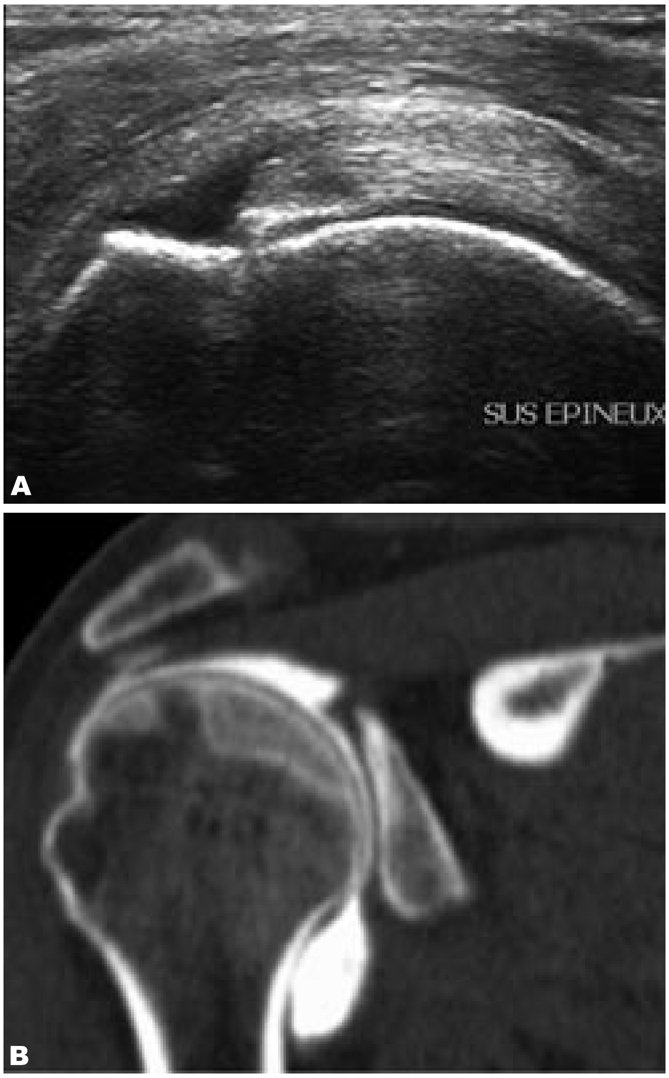

Fig. 3. A 42–year-old woman with articular-surface partial-thickness tear of the supraspinatus tendon.
A. Coronal view of the supraspinatus tendon on ultrasound. The tendinous abnormality was interpreted as a full-thickness tear.
B. Coronal view of the supraspinatous tendon on CT arthrography only shows an articular surface partial thickness tear.

diagnostic accuracy of US is good in regard to identifying and measuring the size of partial- and full-thickness rotator cuff tears.[1] Ultrasonography is such a reliable, fast, inexpensive and easily tolerable diagnostic tool for the patient that may be used as a primary modality for evaluating the rotator cuff, providing the examiner with a detailed knowledge of the shoulder anatomy. It uses a standardized examination technique, and has a thorough understanding of the potential pitfalls, limitations and artifacts.

Ultrasonographic criteria for the diagnosis of rotator cuff tears include direct and indirect signs. Direct signs are non-visualization or absence of the rotator cuff, focal partial- or full-thickness discontinuity of the rotator cuff, focal thinning of the rotator cuff, loss of convexity of the outer border of the rotator cuff and hypoechoic defect of the articular or bursal side of the rotator cuff or within a tendon. Indirect signs are cortical outpouchings (pitting) at the insertion of the rotator cuff tendons, fluid in the joint cavity and subacromial/subdeltoid bursa, the ability to compress

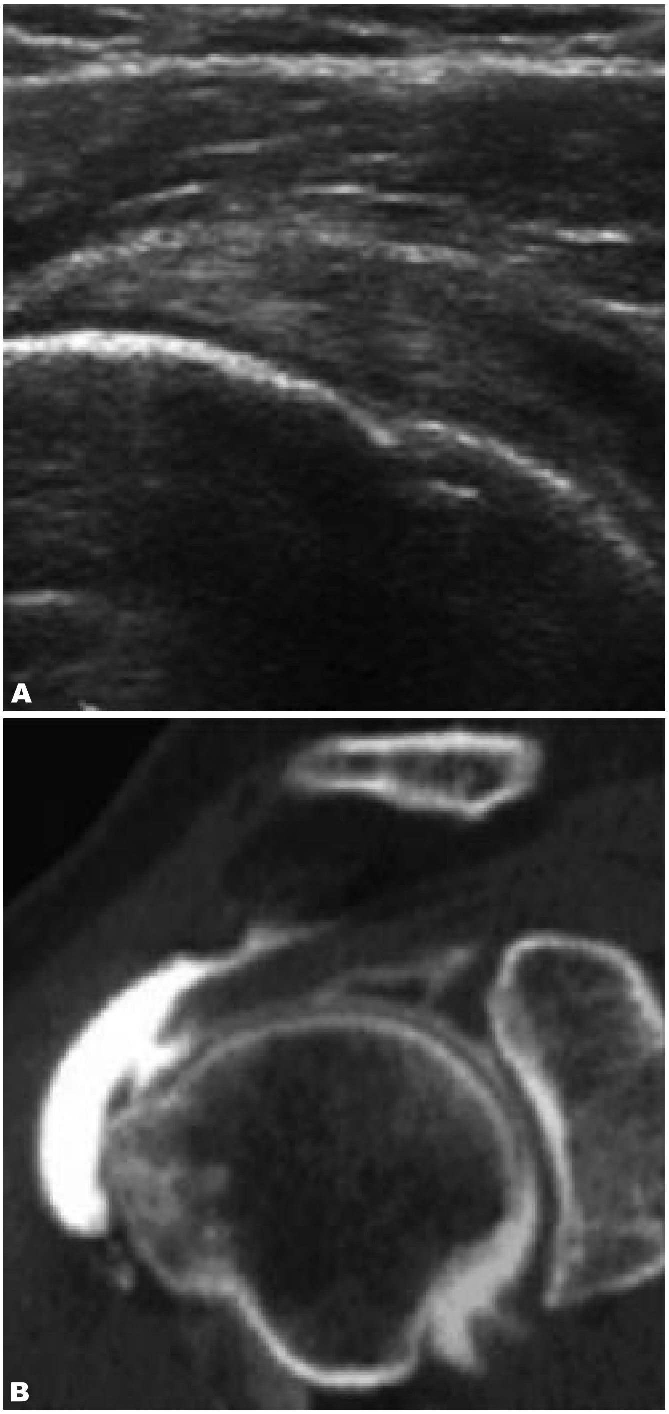

Fig. 4. A 56-year-old man with full-thickness tear of the supraspinatus tendon
A. Coronal ultrasonographic view of the supraspinatus tendon showing a normal continuous and fibrillar appearance. Ultrasound of the same patient also showed a double (joint and subacromial subdeltoid bursa) effusion.
B. Arthro-CT showed a supraspinatus full thickness tear.

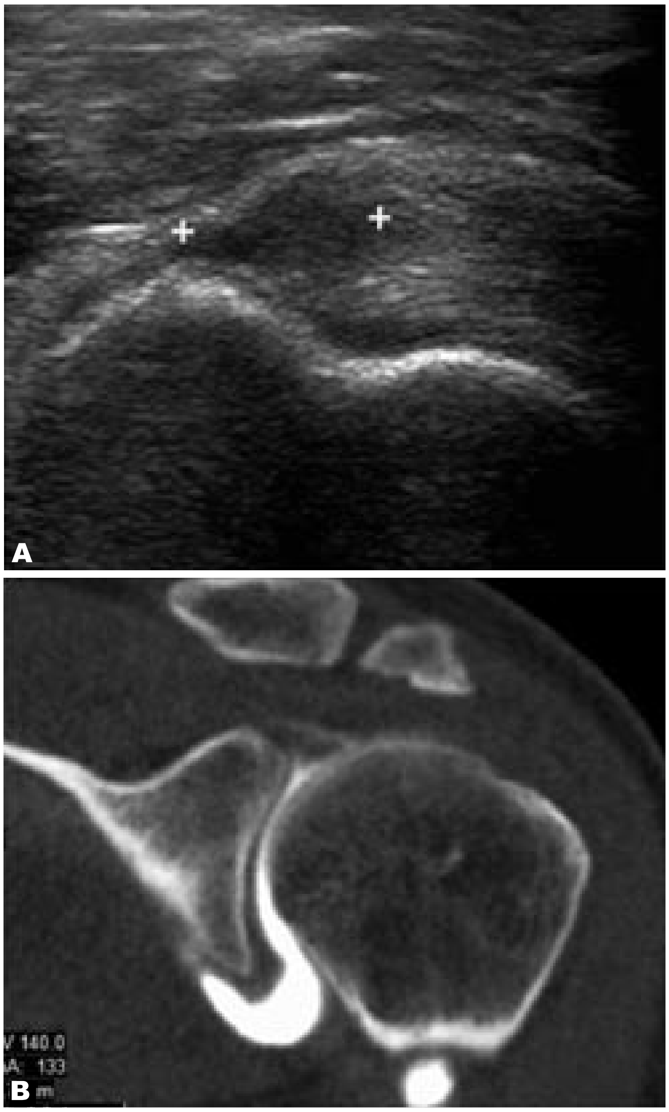

Fig. 5. A 50-year-old man with tendinosis of the supraspinatus tendon.
A. Coronal US view of the supraspinatus tendon: hypoechoic foci, interpreted as a full-thickness tears.
B. CT arthrography did not show any tear in the supraspinatus tendon.

Table 1. Diagnostic Efficacy Indices and Agreement of Ultrasound versus CT Arthrography in each Rotator Cuff Tendon Tear

Type of Injury	TP	FN	TN	FP	Se(%) (95 CI)	Sp(%) (95 CI)	PPV(%) (95 CI)	NPV(%) (95 CI)	PLR	NLR	Kappa	P Value
Full-Thickness Tears of the Supraspinatus	40	10	5	9	80 (66-90)	36 (14-64)	82 (68-91)	33 (13-61)	1.24	0.56	0.15	0.286
Partial-Thickness Communicating Tears of the Supraspinatus	9	20	31	4	31 (16-51)	89 (72-96)	69 (39-90)	61 (46-74)	2.72	0.78	0.21	0.052
Full-Thickness Tears of the Infraspinatus Tendon	9	13	35	7	41 (22-63)	83 (68-93)	56 (31-79)	73 (58-84)	2.46	0.71	0.11	0.033
Partial-Thickness Tears of the Infraspinatus Tendon	7	22	30	5	24 (11-44)	86 (69-95)	58 (29-84)	58 (43-71)	1.69	0.89	0.11	0.315
Full-Thickness Tears of the Subscapularis Tendon	10	5	48	1	67 (39-87)	98 (88-100)	91 (57-100)	91 (79-97)	32.7	0.34	0.71	<0.001
Partial-Thickness Tears of the Subscapularis Tendon	5	9	46	4	36 (14-64)	92 (80-97)	56 (23-85)	84 (71-92)	4.46	0.70	0.32	0.019
Full-Thickness Tears of the Biceps Tendon	4	1	57	2	80 (30-99)	97 (87-99)	67 (24-94)	98 (90-100)	23.6	0.21	0.70	<0.001
Long Biceps Subluxation	2	4	58	0	33 (6-76)	100 (92-100)	100 (20-100)	94 (84-98)	----	0.67	0.48	0.007

TP: True positive, FN: False Negative, TN: True Negative, FP: False Positive, Se: Sensitivity, Sp: Specificity, PPV: Positive Predictive Value, NPV: eg

the deltoid muscle into a cuff defect or against the humeral head (naked tuberosity sign) and a bright aspect of the humeral cartilage (cartilage interface sign or uncovered cartilage sign).[2] The direct signs were only considered reliable in our study.

False positive and false negative US results may be due to various causes. The main causes of misinterpretation of ultrasound findings may be classified in four groups, the US technique, the anatomy, the lesion type and the patient.[7-9]

Ultrasound examinations should be performed with high-resolution linear-array transducers (multi-frequency broadband, 7.5-15MHz) with adequate tissue penetration.

Small- or partial-thickness rotator cuff tears may be missed due to suboptimal focusing, which diminishes spatial resolution. The recent technical advances (transmit compounding, extended-field acquisition, three-dimensional US acquisition, four-dimensional imaging) are thought to improve the diagnostic accuracy of US. Rotator cuff tears may also be missed due to limited movements of the shoulder especially for the supraspinatus and subscapularis tendons. When shoulder motion is not limited, the dynamic evaluation helps to identify non-retracted full-thickness rotator cuff tears by looking for the separation of the margins of a tear. It also allows better visualization of small full-thickness tears.

In order to discover insignificant fluid collections in the bicipital tendon sheath and subacromial/subdeltoid bursa the transducer pressure should be decreased.[7]

The radiologists' experience in musculoskeletal ultrasound is very important to avoid these technical and anatomical pitfalls.[3,10]

The variation of individual echogenicity is quite wide. It results from the reflexive difference of subcutaneous tissue and depends on the subcutaneous fat thickness and the patient's age. Despite the development of high-frequency transducers, the depiction of rotator cuff tears in obese or muscular patients may be limited, especially for partial-thickness or small full-thickness tears.

Pain and stiffness of the shoulder may also constitute an ultrasound technical limitation. A wide variation in US appearance may exist on ultrasound for the same lesion type.

Several studies have demonstrated a good sensitivity and specificity of ultrasound in the diagnosis of full-thickness rotator cuff tears, similar to MRI.[11-15]

Full-thickness tears usually appear as an interruption of the normal tendon image, an important tendon thinning less than 3 mm or an anechoic intratendinous image involving all the tendon thickness. However, a full-thickness tear may appear hyperechoic, which causes false negatives.[16] At the acute phase, a full-thickness tear may also present as simple modifications of tendon echo-structure leading the observer to look for indirect signs such as joint and/or subacromial bursal effusion.

The flattening of the superficial aspect does not systematically indicate a full-thickness tear. This US sign may be presented either in partial-thickness bursal surface tears or after surgical re-insertion of the tendon.

Rotator cuff tendons may be thinned without being torn, especially after glenohumeral dislocation and in rheumatoid arthritis; the mean thickness of an intact rotator cuff tendon is 4.7 mm[17] An internal biceps tendon dislocation may mimic a complete tear if the biceps tendon is not found in the bicipital groove. In case of dislocation, the biceps tendon is usually found to be either in front of or behind the subscapularis tendon and rarely into an intratendinous subscapularis tear. In case of complete biceps tear, fatty degeneration of the long biceps muscles allows diagnostic confirmation.

In our study, US had a low specificity in the diagnosis of full-thickness tears when all tendons are considered together (84% Se and 31% Sp) or when the supraspinatus tendon is considered alone (80% Se and 36% Sp). However, US had a better specificity in diagnosing the infraspinatus (83% Se and 41% Sp) and subscapularis (98% Se and 67% Sp) full-thickness tears.

The low specificity of US in full-thickness tears may be due to the small number of patients having intact rotator cuff tendons or patients without any full-thickness tears. False positive US results are mainly due to confusions between articular-surface partial-thickness tears or foci of tendinopathy with full-thickness tears.

The false negative results of US full-thickness tears in our study may be explained by the small tear size, while for the infraspinatus tendon it may be due to the difficulty to distinguish the distal end of the supraspinatus and infraspinatus tendon, making posterior extensions of the supraspinatus tears to the infraspinatus tendon often misdiagnosed.

Either partial-thickness or full-thickness rotator cuff tears are difficult to detect when they are located in an often coexistent area of tendinosis. Calcium deposits in the rotator cuff tendons and/or the subacromial/subdeltoid bursa may cause false negative results because tears may be obscured by the shadow of these calcifications.

Non diastasis of the ruptured tendon fibers may also cause misinterpretation. A recent partial-or full-thickness tear is accompanied by fluid (i.e. hematoma). The surrounding fluid enhances the ultrasound signal, which is favorable for the depiction of rotator cuff tears. In a long-standing tear, fluid may be absorbed. Partial-and full-thickness rotator cuff tears may then be more difficult to depict.

The detection of fluid in the subacromial/subdeltoid bursa isolated or associated with joint effusion is highly specific (96% and 99%, respectively) and has a high positive predictive value (70% and 95%, respectively) for the diagnosis of associated rotator cuff tears in symptomatic patients.[8]

Moreover, granulation or scar tissue, echogenic fluid due to debris, or thickened bursa may fill in partial- or full-thickness rotator cuff tears, thereby impeding the sonographic visualization as well as CT arthrography detection.

In our study, ultrasound sensitivity was lower for partial thickness tears than full-thickness tears. US specificity ranged from 86% to 97% for all tendons regardless of the tear location. The low US sensitivity may be explained by the confusion between articular-surface false thickness tears and full-thickness tears on US.

This study demonstrates that the diagnostic performance of US in the detection of partial-thickness tears is improved when a joint effusion alone or associated with subacromial/subdeltoid bursal effusion is present with the positive predictive value of 89% (Table 2). To our knowledge, no previous study has demonstrated the influence of joint effusion or joint and subacromial/subdeltoid bursal effusion on the accuracy of US in the diagnosis of partial-thickness tears.

The choice of multislice CT arthrography as a gold standard may be discussed. We chose arthro-CT because of its high spatial resolution and because it had a greater accessibility compared to MRI in our institution. CT arthrography is known to be very performant either in the diagnosis of rotator cuff full-thickness tears or in partial-thickness tears which communicate with the joint cavity. In fact, the passage of contrast from the articular cavity to the subacromial bursa is well demonstrated by CT arthrography in all tendons and even in very small tears. Although there are some limitations, CT arthrography is a performance diagnostic tool for rotator cuff tears that communicate with the joint cavity. This diagnostic performance is not modified by the patients' age, respiratory problems, or claustrophobia. Moreover, this tool has a better accessibility and lower cost than MRI. Bursal-surface partial thickness tears are far less frequent. They are not included in our study because they are missed by CT arthrography.

According to some authors,[18,19] some articular-surface tears with horizontal cleavages are only seen in the abduction external rotation of the arm (ABER position) either on CT arthrography or arthro-MRI. These authors particularly recommend ABER position for the diagnosis of infraspinatus cleavages.[20]

A recent study has compared CT arthrography to arthro-MRI.[21] It showed that CT arthrography was as performant as arthro-MR in the diagnosis of full-thickness tears. The appearance of the torn tendon was better depicted by arthro-MRI, while the presence or absence of an intratendinous cleavage of the infraspinatus was better demonstrated by CT arthrography. The authors of this study conclude that the constant image quality of CT arthrography makes this method better than arthro-MR, but in case of partial thickness tears, arthro-MR is the preferred investigation method. Another advantage of arthro-MR is to show the bursal-surface partial-thickness tears which are not demonstrated by CT arthrography unless an opacification of the subacromial bursa is performed (arthro-burso-CT). This kind of tear forms up to 45% of rotator cuff tears.[22] It is usually well-diagnosed by high resolution US, but no isolated tear of this type has been observed in our series.

This study was double-blind and prospective. All US and CT examinations were standardized, which led to more objective data. However, there are some methodological limits mainly due to a selection bias; the indication of CT arthrography was directly related to the US results which means patients with a normal rotator cuff US result did not undergo further CT arthrography examination.

For statistical analysis, first, we considered each

Table 2. Comparison of Ultrasound Diagnostic Performance in the Detection of Partial Thickness Tears According to the Presence of Joint Effusion or Joint and Subacromial/Subdeltoid Bursal Effusion

	Sensitivity(%) (95 CI)	Specificity (%) (95 CI)	PPV (%) (95 CI)	NPV (%) (95 CI)	P (Fisher's Exact Test)
Partial-Thickness Tears (Independently from Effusions)	76 [59.4-87.1] N=41	44 [23.9-65.1] N=23	71 [54.6-82.8]	50 [27.9-72.1]	0.114
Partial-Thickness Tears (with Joint Effusion)	76 [54.5-89.8] N=25	70 [35.4-91.9] N=10	86 [64.0-96.4]	54 [26.1-79.6]	0.020
Partial-Thickness Tears (with Joint and Subacromial/Subdeltoid Bursal Effusion)	80 [55.7-93.4] N=20	67 [24.1-94.0] N=6	89 [63.9-98.1]	50 [17.4-82.6]	0.051

CI: confidence interval

tendon separately, then each type of rotator cuff tear. For this second analysis, the patient was considered "negative" for a type of tear only if all his tendons did not have that type of tear. Although this decision was made in order to count every patient only once, it might have affected the final results. For instance, full-thickness tears were present in 80% of patients so this could have affected the results for partial-thickness tears.

It should also be noted that although all our radiologists were experienced in musculoskeletal imaging, they did not have the same experience, which could affect their diagnostic performance. Furthermore, inter-observer and intra-observer reproducibility have not been evaluated in our study.

The overall conclusion is that high resolution US is a reliable, non-invasive diagnostic tool for the assessment of rotator cuff disorders. US sensitivity is better for large full-thickness tears than small full-thickness and partial-thickness tears. However, US has a good specificity for the diagnosis of partial-thickness tears. Moreover, the presence of joint effusion or double effusion significantly increases the US diagnostic accuracy for partial-thickness tears.

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