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ORIGINAL ARTICLE

Diagnostic Utility of US for Detecting Rotator Cuff Tears in Rheumatoid Arthritis Patients: Comparison with Magnetic Resonance Imaging

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Background: Ultrasonography (US) is being increasingly used in clinical practice to detect rotator cuff tears (RCTs) in patients with rheumatoid arthritis (RA) who have shoulder pain. The major aim of this study was to determine the diagnostic utility of US and magnetic resonance imaging (MRI) for detecting RCTs in patients with RA who have persistent shoulder pain.
Patients and methods: With standardized procedures, US and MRI examinations of the shoulder were performed in 36 patients with RA who had persistent shoulder pain prior to arthroscopic intervention. Within 1 month after US and MRI examination, arthroscopic repair was performed. Arthroscopic findings were used as the gold standard for the diagnosis of RCTs.
Results: Full-thickness RCTs in 28 patients with RA (77.8%) and partial-thickness RCTs in eight patients (22.2%) were identified using arthroscopic inspection. With arthroscopic findings as the gold standard, the sensitivity and accuracy of US in detecting full-thickness RCTs were 92.9% and 89%, respectively, whereas those for MRI were 96.4% and 90%, respectively. In detecting partial-thickness RCTs, the sensitivity and accuracy were 62.5% and 75.0%,

Conflicts of interest: The authors declare that they have no competing interests.

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respectively, for US, in contrast with 87.5% and 88%, respectively, for MRI. The overall agreement between US and MRI was 89.3% in detecting full-thickness RCTs and 75.0% in detecting partial-thickness RCTs. US demonstrated levels of sensitivity similar to that of MRI in detecting posterior recess synovitis, tenosynovitis, and subacromial-subdeltoid bursitis.
Conclusion: With a good agreement with MRI, US was shown to be a highly sensitive and accurate imaging modality in detecting full-thickness RCTs for patients with RA who have shoulder pain, but appeared to have lower sensitivity in detecting partial-thickness RCTs compared with MRI.

Introduction

Rheumatoid arthritis (RA), a chronic inflammatory disease, is characterized by synovial hyperplasia and bone erosions [1]. The proliferative synovitis of RA commonly involves both the glenohumeral joint and diverse periarticular soft tissues of the shoulder complex [2,3]. Persistent synovitis and periarticular inflammation may result in bone erosion, cartilage destrunction, and eventual rupture of the rotator cuff or biceps tendon. During the first 2 years of onset of RA, approximately 50% of patients develop shoulder symptoms, with 80—90% of them complaining of shoulder pain throughout the entire disease course [2,4,5]. However, the detection of rotator cuff tears (RCTs) and shoulder joint pathologies may often go unrecognized because of insidious onset of RA, deeply seated shoulder joint, or the compensatory mechanism of scapulothoracic motion and neighboring joints [5,6].

Although plain or conventional radiographic assessment of peripheral joints has served as a standard tool for documenting the extent of joint destruction in RA, evaluation of the complex anatomical structure of the shoulder is difficult. Ultrasonography (US), an imaging modality, is now widely used in rheumatology research and clinical practice to visualize joints and soft tissues of patients with various rheumatic diseases. US is useful for detecting synovitis, bone erosion, and soft-tissue changes in the shoulder such as synovitis, bursitis, tenosynovitis, and RCTs [7—16]. The frequency of abnormal US findings of shoulder joints in patients with RA differs depending on the enrolled patient population, the quality of the US equipment, and the protocol for shoulder evaluation. Through US examination, RCTs were detected in 5.5—37.2% of rheumatoid shoulder joints [11—14]. Over the past 10 years, US supplemented by power Doppler US has been valuable in detecting vascularity and determining the causes of synovitis or RCTs [14—16].

Currently, magnetic resonance imaging (MRI) is widely used to assess painful shoulder pathology [5,6,14,17—19]. In comparison with US, contrast-enhanced MRI is significantly more sensitive in evaluating rheumatoid shoulders, and less operator dependent in detecting synovitis, tenosynovitis, bursitis, and RCTs [19]. Although the comparisons both between US and contrast-enhanced MRI and between US and physical examination have been reported regarding the evaluation of rheumatoid shoulder [5,13,14], the comparison of the performance in detecting RCTs between US and MRI, using arthroscopic findings as the gold standard of diagnosis, has not been studied in patients with RA.

In this study, we used US to investigate abnormalities of rheumatoid shoulder, compared US findings with those of MRI, and evaluated the concordance grade between US and MRI in their ability to detect RCTs and other joint pathologies in patients with RA and persistent shoulder pain, with arthroscopic findings as the diagnostic gold standard. In RA, additional pathologies, such as synovitis, may lead not only to articular destruction, but also RCT. Therefore, we also examined via US the roles played by the additional pathologies such as bursitis, synovitis, and tenosynovitis in the occurrence of RCTs in patients with RA.

Methods

Patients

Thirty-six RA patients (33 women and 3 men, mean age $\pm$ standard deviation, 53.1 $\pm$ 9.4 years) who had received arthroscopic repair for RCTs were enrolled in this retrospective study. Prior to arthroscopic intervention, all of them had suffered persistent shoulder pain for more than 3 months prior to undergoing US and subsequent MRI examinations of the shoulder. The diagnosis of RA was made based on the 2010 RA classification criteria of the American College of Rheumatology (ACR)/European League Against Rheumatism (EULAR) collaborative initiative [20]. Disease activity of RA at the time of US examination was assessed by the 28-joint disease activity score (DAS28) [21]. Active disease was defined as DAS28 $>$3.2 [22]. Patients in whom shoulder pain or instability developed after trauma to the shoulder area were excluded. Written consent from each participant was obtained for imaging examination and arthroscopic surgery, and the Institutional Review Board of Taichung Veterans General Hospital, Taichung, Taiwan approved this retrospective study.

US examination of the shoulder joint

Each US examination was performed by either of the two rheumatologists (K.-L.L. and H.-H.C.) who each had 10 years' experience with US. US examination techniques were standardized for 10 sections throughout the affected shoulder joint and performed as described by Bruyn et al [16]. The ultrasonic assessments of shoulder joints were performed

with a General Electric LOGIC 500 unit (GE, Milwaukee, WI, USA) using a 6-13 MHz linear array transducer. Rotator cuff tendons were examined for the presence of partial-thickness or full-thickness tears in a longitudinal and a transverse plane on static and dynamic positions. Synovial structures of the shoulder, including subacromial-subdeltoid (SA-SD) bursa, sheath of the long biceps tendon, and axillary as well as the posterior recess of the glenohumeral joint, were examined for the presence of effusions, bursitis, tenosynovitis, and synovitis. Power Doppler assessment of synovial sites of the shoulder was carried out with settings standardized to a pulse repetition frequency of 400—500 Hz and low wall filters. The power Doppler gain was adjusted to a level just below the disappearance of color signs as recommended by Rubin et al [23]. The following definitions for the classification of US findings were used [16,24,25]: synovitis was characterized on US by an anechoic or hypoechoic area with elevation of the capsule on the axillary longitudinal section and/or dorsal transverse section and/or ventral transverse and longitudinal sections; presence of tenosynovitis was assumed when the echogenic tendon was surrounded by a hypoechoic band with hypervascularity on color Doppler scan in the transverse and longitudinal sections; bursitis was characterized by a widened anechoic or hypoechoic margin in the area of the SA-SD or subcoracoid bursa with hypervascularity on color Doppler scan; cortical irregularities >2 mm of the humeral head were classified as erosions when they were visualized in two planes perpendicular to each other. Rotator cuff tendons were investigated for the presence of full-thickness or partial-thickness tears in a longitudinal and a transverse plane in static and dynamic positions. The diagnosis of full-thickness tear was as defined as nonvisualization of tendon or complete fiber discontinuity, and partial-thickness tear was defined as localized absence and focal discontinuity [16,24—26].

MRI examination of the shoulder joint

Assessment of the affected shoulder by MRI was performed on two 1.5 T scanners (Symphony Tim-System and Magnetom Area-Tim Dot System; Siemens, Erlangen, Germany) using a delicate shoulder coil. The patients underwent MRI within 1—2 weeks of surgical intervention, and their medication remained unchanged during this time. The following sequences were used: fast spin-echo (FSE) proton-weighted sequence [repetition time (TR) of 3000 milliseconds, echo time (TE) of 25 milliseconds] in an axial and oblique sagittal plane with oblique coronal slices perpendicular and parallel to the course of the tendon of the supraspinatus, respectively, and FSE T2-weighted fat- suppressed images (TR of 4500—5000 milliseconds, TE of 100 milliseconds) in axial, oblique sagittal, and oblique coronal planes. After selection of a suitable slice on which abnormal changes were visualized, a contrast-enhanced MRI [intravenous injection of the gadolinium diethylenetriaminepentaacetic acid (GD-DTPA); 0.1 mmol/kg of body weight] was performed using FSE T1-weighted fat-suppressed sequence (TR of 500 milliseconds, TE 10 milliseconds) in axial, oblique sagittal, and oblique coronal planes were performed. The imaging slices thickness (SL) was 3 mm and the fields of view (FOV) ranged from 140 mm to 160 mm. The MRIs were evaluated by two radiologists who were in consensus and had no knowledge of the results of the US. The MRIs were analyzed for the presence or absence of the same structures that were visualized by US. The MRI criterion for full-thickness tears was total interruption of involved tendon without contrast enhancement on fat-suppressed T1-weighted sequences; for partial-thickness tears, an intra-articular or intrabursal area with a high signal on T2-weighted sequences without contrast enhancement on fat-suppressed T1-weighted sequences; for synovitis, an enhancing material seen on the fat-suppressed T1-weighted sequences [27]; for tenosynovitis, an increased signal sequences along the course of tendons on the T2-weighted sequences, the short tau inversion recovery (STIR) sequence, or the fat-saturated T1-weighted turbo spin-echo sequences after administration of contrast medium; for bursitis, hyperintensities in the areas of the SA-SD bursa or of the subcoracoid bursa; for effusion, an intra-articular or -bursal area with a high signal on T2-weighted sequences without contrast enhancement on fat-suppressed T1-weighted sequences; and for bone erosion, a shoulder joint-related cortical defect with a hypointense signal on T1-weighted spin-echo sequences and hyperintensity on the STIR sequences [14,27]. Nonenhancing hypointense joint-related substrates were counted as erosion only if they were at least 2 mm in size.

Arthroscopic examination of the shoulder joint

Arthroscopic surgery was performed by one of the staff (C.-P.C.), an experienced shoulder surgeon. The surgical repair consisted first of arthroscopic assessment of all rotator cuff tendons by inspection of the glenohumeral joint and the subacromial space. A partial-thickness RCT was diagnosed if a partial interruption of rotator cuff tendon was visualized and a full-thickness RCT if free communication was observed between the bursal and humeral sides of the cuff tendon. In addition, the arthroscopic criterion for synovitis was redness (defined as vascular dilatation and congestion) and villous formation (defined as an increase in finger-like, polyp-like, and clubbed villi) of synovium; for tenosynovitis, redness of the sheath along the course of tendons; and for bursitis, redness of bursa with or without villous formation [28]. The diagnosis of synovitis and bursitis was further confirmed by typical histological findings of excisional specimens from arthroscopic surgery. However, arthroscopic diagnosis of synovial effusion was somewhat subjective and inaccurate, and arthroscopic evaluation cannot easily detect small erosion of the shoulder joint.

Statistical analysis

Results are presented as the mean $\pm$ standard deviation (SD) or number (percentages). US and MRI findings were recorded preoperatively and were compared with arthroscopic findings with regard to RCTs. The χ^2 test was used to compare binary variables. We assessed the level of concordance grade between US and MRI in detecting RCTs and joint pathology using the χ^2 tests. We used the χ^2 test to determine the diagnostic sensitivity and accuracy of US as well as MRI in detecting RCTs using arthroscopic findings

as the diagnostic gold standard. Moreover, we constructed a logistic regression model to evaluate the effects of shoulder pathologies shown by US on the occurrence of RCTs in patients with RA. A p value <0.05 was considered statistically significant.

Results

Baseline characteristics of 36 patients with RA

As illustrated in Table 1, most patients with RA (30, 83.3%) had active disease (mean DAS28 ± SD, 5.36 ± 0.95) and 25 (69.4%) patients had late-stage (Stage III and Stage IV) RA as determined by radiography at the time of arthroscopic repair for RCTs. Twenty-eight (77.8%) patients had full-thickness RCTs, and eight (22.2%) patients had partial-thickness RCTs at the time of arthroscopic repair. The most commonly involved tendon was supraspinatus tendon (27 patients, 75.0%), followed by both supraspinatus tendon and infraspinatus tendon (7 patients, 19.4%). Three RCTs were detected by MRI but not by US, and the infraspinatus tendon was the location of those RCTs.

Table 1 Clinical characteristics and laboratory findings in 36 patients with rheumatoid arthritis complicated with rotator cuff tear.[a]

Characteristics	Patients with RA
Mean age (y)	53.1 ± 9.4
Female	33 (91.7)
Disease duration (y)	10.1 ± 3.7
Radiographic stage (III+IV)	25 (69.4)
RF positivity	26 (72.2)
ESR (mm/1st h)	41.9 ± 21.2
C-reactive protein (mg/dL)	2.06 ± 3.36
DAS28	5.00 ± 1.19
Daily steroid dose (mg)	5.2 ± 2.0
DMARDs used	
Methotrexate	32 (88.9)
Sulfasalazine	25 (69.4)
Hydroxychloroquine	23 (63.9)
TNF-α inhibitors (etanercept or adalimumab)	6 (16.7)
Rotator cuff tear	
Right shoulder	23 (63.9)
Left shoulder	13 (36.1)
Full-thickness tear	28 (77.8)
Partial-thickness tear	8 (22.2)
Involved tendons	
Supraspinatus tendon	27 (75.0)
Supraspinatus + infraspinatus tendons	7 (19.4)
Supraspinatus + subscapularis tendons	1 (2.8)
Subscapularis tendon	1 (2.8)

DAS28 = disease activity score for 28-joints; DMARDs = disease-modifying antirheumatic drugs; ESR = erythrocyte sedimentation rate; RF = rheumatoid factor; TNF-α = tumor necrosis factor-α.

[a] Data are presented as mean ± standard deviation or n (%).

US and MRI findings of rheumatoid shoulder joint with RCTs

Of 28 patients with full-thickness RCTs, US disclosed full-thickness tears in 26 shoulders (92.9%) and MRI detected full-thickness tears in 27 shoulders (96.4%, Table 2). Among eight patients with partial-thickness RCTs, US detected partial-thickness tears in five shoulders (62.5%) and MRI detected partial-thickness tears in seven shoulders (87.5%). Regarding signs of inflammation and other joint pathologies based on arthroscopic findings (Table 2), we demonstrated that both US and MRI had comparable rates in detecting posterior synovitis, tenosynovitis, and SA-SD bursitis. However, US had significantly lower rates in detecting axillary synovitis than those of MRI. US had a lower detection rate (52.8%) in identifying humeral head erosions when compared to that of MRI (66.7%), but this was not of statistical significance ($p = 0.063$).

Agreement levels and κ coefficients between US and MRI

The overall agreement with a κ coefficient between US and MRI is illustrated in Table 2. The overall agreement between US and MRI was good in detecting full-thickness RCTs, posterior synovitis, tenosynovitis, SA-SD bursitis, and humeral head erosions (κ coefficient = 0.717, agreement level 72%). The overall agreement between US and MRI was poor in detecting partial-thickness RCTs and axillary recess synovitis.

Diagnostic performance of US and MRI in detecting RCTs using arthroscopic findings as the gold standard

Our results showed that full-thickness RCTs could be detected by US in patients with RA with high sensitivity (92.9%) and high accuracy (89.0%); and partial-thickness RCTs could be detected by US with relatively low sensitivity (62.5%) and accuracy (75.0%). Our results also showed that full-thickness RCTs could be detected by MRI with high sensitivity (96.4%) and high accuracy (90.0%); and partial-thickness RCTs could be detected by MRI with high sensitivity (87.5%) and high accuracy (87.5%).

Logistic regression analysis of the effects of shoulder joint pathologies detected by US on the occurrence of RCTs in patients with RA

Using US examination, our results showed that the presence of shoulder joint synovitis could predict the occurrence of RCTs [odds ratio (OR), 13.71; 95% confidence interval (CI), 1.31–143.44, $p < 0.05$ in univariate analysis; OR 14.56, 95% CI 1.14–186.0, $p < 0.05$ in multivariate analysis] in patients with RA.

Discussion

US has been increasingly used in clinical practice to detect RCTs in patients with RA and who have persistent shoulder

Table 2 The detection rates of rotator cuff tears and other joint pathologies using ultrasonography and magnetic resonance imaging using arthroscopic findings as a gold standard, and the agreement levels between ultrasonography and magnetic resonance imaging in 36 patients with rheumatoid arthritis.

Arthroscopic findings	US	MRI	Overall agreement	
	n (%)	*n* (%)	%	κ coefficient
Full-thickness RCTs ($n = 28$)	26 (92.9)	27 (96.4)	89.3	0.650
Partial-thickness RCTs ($n = 8$)	5 (62.5)	7 (87.5)	75.0	0.385
Posterior recess synovitis ($n = 34$)	25 (73.5)	30 (88.2)	86.1	0.625
Axillary recess synovitis ($n = 28$)	5 (17.9)*	15 (53.6)	57.2	0.180
Tenosynovitis ($n = 30$)	16 (53.3)	18 (60.0)	94.4	0.889
SA-SD bursitis ($n = 34$)	21 (61.8)	27 (79.4)	86.1	0.667

*$p < 0.01$, **$p < 0.005$, versus MRI, determined by the χ^2 test with McNemar examination The overall agreement levels between US and MRI for detecting RCTs and joint pathology using the χ^2 tests.
MRI = magnetic resonance imaging; RCT = rotator cuff tear; SA-SD bursitis = subacromial-subdeltoid bursitis; US = ultrasonography.

pain, which makes it important to evaluate the reliability of US to identify RCTs in patients with this disease. The current study is the first attempt to assess the diagnostic utility of both US and MRI for detecting RCTs in Taiwanese RA patients using arthroscopic findings as the diagnostic gold standard. Our results show that US could detect a full-thickness RCT in patients with RA with high sensitivity (92.9%), which is consistent with the findings of previous studies, including a meta-analysis and Cochrane review indicating that US has a good diagnostic accuracy in identifying full-thickness RCTs [26,29—33]. Moreover, there was an excellent agreement between US and MRI regarding their diagnostic performance in detecting full-thickness RCTs, which was also consonant with other previous findings [32—34]. However, US could only detect partial-thickness RCTs with relatively low sensitivity (62.5%), as reported in a meta-analysis and Cochrane review (66.7% and 52%, respectively) [32,33]. In addition, there were three patients whose RCTs could be detected by MRI but not by US, and the involved locations were all infraspinatus tendon, which might not be easily accessed and evaluated by US.

Also using arthroscopic findings as the gold standard, full-thickness RCTs in patients with RA could be detected by MRI with high sensitivity (96.4%), consistent with the findings of previous reports [32,33]. Similar to US, partial-thickness tears were detected by MRI with relatively lower sensitivity (87.5%) in our patients with RA. Both results were consistent with previous research findings showing that MRI may have poor sensitivity in detecting partial-thickness RCTs [32,33].

Moreover, the sensitivity of US in detecting partial-thickness RCTs was much lower than that of MRI (62.5% vs. 87.5%), as was shown in the findings of a Cochrane review (52% vs. 74%) [33]. Nevertheless, US has certain great advantages, including low cost and portability as well as lack of radiation and contraindications. Therefore, the effectiveness of US as an alternative diagnostic tool in detecting RCTs has already been demonstrated in previous studies [32,33,35], and patients may prefer US examination to MRI [36].

Early diagnosis of RCTs in patients with RA is crucial for initiating optimal treatment in that untreated tears may extend with increasing pain [37] and cause irreversible fatty degeneration with atrophy of shoulder musculature [38]. Therefore, surgical repair should be carried out early in the development of RCTs, with time-to-treatment being an important factor in determining the long-term outcome of patients with RA.

Despite the frequent involvement of the shoulder in patients with RA [5,13], joint pathologies with RCT are often neglected. US of the shoulder could reveal the pathologies of the SA-SD bursa, synovial membranes, and tendon sheaths, and therefore provide a noninvasive evaluation to identify the mechanisms of RCTs [11,13,14,16,39]. With arthroscopic findings as the diagnostic gold standard, we found a high proportion of synovitis and SA-SD bursitis in patients with RA and RCTs, suggesting their possible pathogenic association with the emergence of RCTs. Furthermore, it was also demonstrated that shoulder synovitis detected by US could predict the occurrence of RCTs, using univariate and multivariate regression analysis (OR 13.71 and 14.56, respectively, both $p < 0.05$). For the diagnosis of tenosynovitis, the arthroscopic finding of redness of the sheath along the course of tendons was essential, whereas the detection of fluid was necessary in US or MRI. With arthroscopic criterion as the gold standard, such discrepancy in the diagnostic criteria could contribute to the low sensitivity of US and MRI in detecting tenosynovitis.

As has been reported [16], we demonstrated that US could reliably assess posterior recess synovitis, tenosynovitis, SA-SD bursitis, and bone erosions, and showed a good diagnostic congruence with MRI. However, we found that US was inferior to MRI (17.9% vs. 53.6%) in detecting axillary recess synovitis, which supports previous findings showing that US cannot reliably identify axillary recess synovitis or distinguish synovial inflammation from effusion in the shoulder joint when compared with MRI [10,16,27]. Such lower sensitivity of US may be partly explained by the different positioning from that in MRI examination, the marked limitation of shoulder elevation in most patients with RA who had RCT, and perfusion changes below the detection threshold. Therefore, the diagnostic performance of US in detecting axillary recess synovitis may be improved by using a smaller transducer to scan the axillary recess in the longitudinal view, or using color Doppler scan, or scanning the axillary recess with a different positioning of the shoulder as in MRI.

There were some limitations in our study. This was a retrospective study that enrolled a limited number of patients with RA. Most patients could not undergo MRI examination on the same day as US and conventional radiography because of the limited availability of MRI. Because the diagnosis of full-thickness RCTs and partial-thickness RCTs are not mutually exclusive, the assessment of diagnostic specificity in each separate group might not be completely accurate. In addition, because the patients enrolled in our study were not an early RA population, the results might not be directly applicable to patients with early RA. Therefore, a long-term study of a larger group of patients, including an early RA population, is required to validate our findings.

In conclusion, both US and MRI are important tools for detecting RCTs in patients with RA with persistent shoulder pain. Early detection of RCTs and RCTs-associated joint pathologies is critical in the prevention of irreversible disability as well as therapeutic planning in order to achieve optimal outcome. Regarding the cost and patients' compliance, US with power Doppler would be recommended as the first choice of radiographic modality for patients with RA with suspected RCTs, in accordance with the imaging algorithms proposed by the Society of Radiologists in US [35].

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References

[1] Choy EH, Panayi GS. Cytokine pathways and joint inflammation in rheumatoid arthritis. N Engl J Med 2001;344:907—16.
[2] Petersson CJ. Painful shoulders in patients with rheumatoid arthritis. Scand J Rheumatol 1986;15:275—9.
[3] Riordan J, Dieppe P. Arthritis of the glenohumeral joint. Baillieres Clin Rheumatol 1989;3:607—25.
[4] Hämäläinen M. Epidemiology of upper limb joint affections in rheumatoid arthritis. In: Baumgartner H, Dvorak J, Grob D, Munziger U, Simmen BR, editors. Rheumatoid arthritis. Current trends in diagnostics, conservative treatment, and surgical reconstruction. Stuttgart: George Thieme Verlag; 1995. pp. 158—61.
[5] Alasaarela E, Suramo I, Tervonen O, et al. Evaluation of humeral head erosions in rheumatoid arthritis: a comparison of US, magnetic resonance imaging, computed tomography and plain radiography. Br J Rheumatol 1998;37:1152—6.
[6] Kieft GJ, Dijkmans BAC, Bloem JL, et al. Magnetic resonance imaging of the shoulder in patients with rheumatoid arthritis. Ann Rheum Dis 1990;49:7—11.
[7] Middleton WD, Reinus WR, Totty WG, et al. Ultrasonographic evaluation of the rotator cuff and biceps tendon. J Bone Joint Surg 1986;68A:440—50.
[8] Seltzer SE, Finberg HJ, Weissman BN, et al. ArthroUS: Gray-scale US evaluation of the shoulder. Radiology 1979;132:467—8.
[9] Koski JM. Axillar US of the glenohumeral joint. J Rheumatol 1989;16:664—7.
[10] Hodler J, Terrier B, von Schulthess GK, et al. MRI and US of the shoulder. Clin Radiol 1991;43:323—7.
[11] Coari G, Paoletti F, Iagnocco A. Shoulder involvement in rheumatic diseases. Sonographic findings. J Rheumatol 1999;26:668—73.
[12] Naranjo A, Marrero-Pulido T, Ojeda S, et al. Abnormal sonographic findings in the non-painful arthritic shoulder. Scand J Rheumatol 2002;31:17—21.
[13] Kim HA, Kim SH, Seo YI. Ultrasonographic findings of the shoulder in patients with rheumatoid arthritis and comparison with physical examination. J Korean Med Sci 2007;22:660—6.
[14] Hermann KG, Backhaus M, Schneider U, et al. Rheumatoid arthritis of the shoulder joint: comparison of conventional radiography, US, and dynamic contrast-enhanced magnetic resonance imaging. Arthritis Rheum 2003;48:3338—49.
[15] Strunk J, Lange U, Kurten B, et al. Doppler sonographic findings in the long bicipital tendon sheath in patients with rheumatoid arthritis as compared with patients with degenerative diseases of the shoulder. Arthritis Rheum 2003;48:1828—32.
[16] Bruyn GAW, Naredo E, Möller I, et al. Reliability of US in detecting shoulder disease in patients with rheumatoid arthritis. Ann Rheum Dis 2009;68:357—61.
[17] Kneeland JB, Middleton WD, Carrera GF, et al. MR imaging of the shoulder: diagnosis of rotator cuff tears. AJR 1987;149:333—7.
[18] Burk DL, Karasick D, Kurtz AB, et al. Rotator cuff tears: prospective comparison of MR imaging with arthrography, US, and surgery. AJR 1989;153:87—92.
[19] Nelson MC, Leather GP, Nirschl RP, et al. Evaluation of the painful shoulder: a prospective comparison of magnetic resonance imaging, computerized tomographic arthrography, US, and operative findings. J Bone Joint Surg 1991;73:707—16.
[20] Aletaha D, Neogi T, Silman AJ, et al. The 2010 rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. Ann Rheum Dis 2010;69:1580—8.
[21] Prevoo MLL, van't Hof MA, Kuper HH, et al. Modified disease activity scores that include twenty-eight-joint counts: development and validation in a prospective longitudinal study of patients with rheumatoid arthritis. Arthritis Rheum 1995;38:44—8.
[22] Smolen JS, Aletaha D, Bijlsma JW, et al., T2T Expert Committee. Treating rheumatoid arthritis to target: recommendations of an international task force. Ann Rheum Dis 2011;70:1519.
[23] Rubin JM, Adler RS, Fowlkes JB, et al. Fractional moving blood volume: estimation with power Doppler US. Radiology 1995;197:183—90.
[24] American College of Rheumatology Musculoskeletal US Task Force. US in American Rheumatology Practice: Report of the American College of Rheumatology Musculoskeletal US Task Force. Arthritis Care Res 2010;62:1206—19.
[25] Wakefield RJ, Balint PV, Szkudlarek M, et al. Musculoskeletal US including definitions for ultrasonic pathology. J Rheumatol 2005;32:2485—7.
[26] Papatheodorou A, Ellinas P, Takis F, et al. US of the shoulder: rotator cuff and non-rotator cuff disorders. Radiographics 2006;26:e23.
[27] Wamser G, Bohndorf K, Vollert K, et al. Power Doppler US with and without echo-enhancing contrast agent and contrast-enhanced MRI for the evaluation of rheumatoid arthritis of the shoulder joint: differentiation between synovitis and joint effusion. Skeletal Radiol 2003;32:351—9.
[28] Kurosaka M, Ohno O, Hirohata K. Arthroscopic evaluation of synovitis in the knee joints. Arthroscopy 1991;7:162—70.
[29] Olive RJ, Marsh HO. US of rotator cuff tears. Clin Orthop 1992;282:110—3.
[30] Turrin A, Capello A, Mauri M, et al. Echography of the shoulder with the patient supine in the diagnosis of rotator cuff rupture. Radiol Med 1997;94:170—5.

[31] Wiener SN, Seitz WH. US of the shoulder in patients with tears of the rotator cuff: accuracy and value for surgical options. AJR 1993;160:103—7.
[32] de Jesus JO, Parker L, Frangos AJ, et al. Accuracy of MRI, MR arthrography, and US in the diagnosis of rotator cuff tears: a meta-analysis. AJR Am J Roentgenol 2009;192:1701—7.
[33] Lenza M, Buchbinder R, Takwoingi Y, et al. Magnetic resonance imaging, magnetic resonance arthrography and US for assessing rotator cuff tears in people with shoulder pain for whom surgery is being considered. Cochrane Database Syst Rev 2013;9: CD009020.
[34] Swen WAA, Jacobs JWG, Algra PR, et al. US and magnetic resonance imaging equivalent for the assessment of full thickness rotator cuff tears. Arthritis Rheum 1999;42:2231—8.
[35] Nazarian LN, Jacobson JA, Benson CB, et al. Imaging algorithms for evaluating suspected rotator cuff disease: Society of Radiologists in US consensus conference statement. Radiology 2013;267:589—95.
[36] Middleton WD, Payne WT, Teefey SA, et al. US and MRI of the shoulder: comparison of patient satisfaction. AJR Am J Roentgenol 2004;183:1449—52.
[37] Mall NA, Kim HM, Keener JD, et al. Symptomatic progression of asymptomatic rotator cuff tears: a prospective study of clinical and sonographic variables. J Bone Joint Surg Am 2010;92: 2623—33.
[38] Kim HM, Dahiya N, Teefey SA, et al. Relationship of tear size and location to fatty degeneration of the rotator cuff. J Bone Joint Surg Am 2010;92:829—39.
[39] Yablon CM, Bedi A, Moraq Y, et al. Ultrasonography of the shoulder with arthroscopic correlation. Clin Sports Med 2013; 32:391—408.