SONOGRAPHY AND MRI IN THE EVALUATION OF PAINFUL ARTHRITIC SHOULDER

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SUMMARY
We evaluated 31 painful shoulders of 30 patients with chronic arthritis by ultrasonography (US) and compared the results with those of magnetic resonance imaging (MRI). Both US and MRI revealed effusion in the subacromial-subdeltoid (SA-SD) bursa, biceps tendon sheath (BTS) and glenohumeral (GH) joint, but MRI was more accurate in depicting joint inflammation because of its ability to visualize synovial hypertrophy. US visualized biceps tendon ruptures equally well as MRI. MRI was better able to reveal full-thickness tear of the supraspinatus tendon, whereas US showed better other changes of the supraspinatus tendon (degeneration or partial-thickness tear). Both of the imaging methods were able to depict erosions of the humeral head, but the locations occasionally differed. Inexpensive and easily available US can be recommended as the first imaging method for the detection of soft-tissue changes in the arthritic shoulder, but in rotator cuff problems both methods may be needed.

KEY WORDS: Ultrasonography, Magnetic resonance imaging, Arthritis, Shoulder, Pain.

The differentiation of causes of shoulder pain is a clinical challenge. There are a wide variety of conditions that may produce similar shoulder pain and dysfunction. In general, rotator cuff diseases play the main role in shoulder abnormalities [1] and 95% of rotator cuff tears are caused by impingement [2]. In rheumatic diseases, inflamed synovial tissue may gradually erode the inferior surface of the rotator cuff, leading to a tear [3]. Mostly, effusions in the subacromial-subdeltoid (SA-SD) bursa, the biceps tendon sheath (BTS) and/or the glenohumeral (GH) joint are associated with rotator cuff disorders, but in rheumatic diseases they may be caused by primary synovial inflammation [4–6].

Clinical assessment of the shoulder with inflammatory arthritis is difficult [7]. The site of pain poorly indicates its origin [8]. Our group has compared clinical and ultrasonography (US) findings of the arthritic shoulder and noted a significant statistical correlation between them. However, the clinical picture of the arthritic shoulder is often complicated by multiple simultaneous inflammatory conditions [9].

In examining an arthritic shoulder, we need an imaging method that is able to detect the extent of soft-tissue and bone manifestations of the inflammatory process. Plain radiography, which is traditionally used to supplement the clinical examination, is not diagnostic of soft-tissue lesions. Both US [10, 11] and magnetic resonance imaging (MRI) [12] have been used to detect rotator cuff tears for the past 10 yr. US visualizes effusions within the BTS [13], in the SA-SD bursa [4, 6, 14] and in the GH joint [15, 16]. MRI is also able to depict these effusions [17], but it is more sensitive [6, 18] and can additionally reveal synovial thickening and pannus tissue formation [19]. In the rheumatoid shoulder, bony erosions are shown by US [20]. Apart from bony erosions, MRI also shows cartilage damage and intraosseus abnormality [19, 21].

The purpose of this study was to evaluate the ability of US to detect shoulder abnormalities of patients with chronic arthritis and shoulder complaints, and to compare the information thus gained with the MRI results.

MATERIALS AND METHODS
Thirty-one painful shoulders of 30 in-patients with chronic arthritis were prospectively evaluated by sonography and MRI. Both shoulders of one patient were evaluated at the different times during the study. Patients were selected from the rheumatology ward for this study, using a painful shoulder and a confirmed rheumatic disease as the selection criteria. Twenty-three of the patients were female and seven were male. Their mean age was 64 (range 40–83) yr. Twenty-six patients had rheumatoid arthritis (20 seropositive and six seronegative), one ankylosing spondylitis, one ulcerative colitis-associated arthritis, one psoriatic arthritis and one juvenile polyarthritis.

The investigators of US and MRI were blind to the mutual results. With the aim of comparing US and MRI, the findings of all structures evaluated by both methods were collected on their own special data sheet.

The operator dependence of ultrasound is well known. Two of the authors with special training in shoulder sonography (EA, a clinician and RT, a radiologist) made the US examination together. The final US diagnosis was determined by consensus; 7.5 MHz linear-array transducers (Aloka SSD-650 and Aloka 2000, Tokyo, Japan) were used. Standard techniques were used for static longitudinal and transverse scanning of the rotator cuff, the biceps tendon and SA-SD bursa [4, 13, 22]. All rotator cuff tendons were evaluated, but only the changes in the supraspinatus tendon were analysed in this study.

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because the rotator cuff tears almost always involve the supraspinatus tendon [10]. Synovial effusion/hypertrophy of the GH joint was evaluated using the techniques reported in earlier studies [9, 16]. The head of the humerus was carefully scanned to detect the presence of any erosion. The sonographic findings were recorded on the data sheet during real-time imaging and documented on film by a laser printer (3M 969 HQ Laser Imager, Minnesota, USA).

The following criteria for the classification of the US findings were used: bursal thickness >2 mm or effusion were considered as effusion/synovial hypertrophy of the SA-SD bursa, a hypoechoic area surrounding the tendon completely as effusion, and thickening and irregular surface of the tendon sheath as synovial hypertrophy in the tendon sheath. Changes in the supraspinatus tendon were classified as full-thickness tear and intrasubstance abnormality of the tendon (including partial-thickness tear or tendinopathy). A full-thickness tear was diagnosed when a defect (hypoechoic zone) extended through the tendon substance or when there was focal thinning with visible margins of the tear and when there was a complete loss of tendon substance. Intrasubstance abnormality of the supraspinatus tendon was recorded when the echostructure of the tendon was heterogeneous with mixed hyper- and hypoechoic regions. Effusion/synovial hypertrophy of the GH joint was evaluated on the glenoid labrum, on the posterior sagittal imaging plane perpendicular to the humeral head and in the axilla using the same criteria as in the earlier studies [9, 16]. Visible erosions and irregularities of the bone surfaces were recorded on the anteromedial and postero-lateral aspects of the humeral head and on the greater tuberosity. Since we were not always able to differentiate between synovial hypertrophy and synovial effusion in the SA-SD bursa, BTS or GH joint by US, we recorded the synovial changes as combined effusion/synovial hypertrophy for statistical analysis, although MRI might have differentiated between them, in order to be better able to compare the synovial findings of the two methods.

MRI was performed by using a 1.0 T MR unit (Magnetom 42 SP, Siemens, Erlangen, Germany) with a bilateral receive-only coil specifically designed for shoulder imaging. After coronal localizing sequences, the following imaging sequences were obtained: pre-contrast T1-weighted axial images (450/15) (TR, TE) with field of view (FOV) of 16 cm and a matrix of 256 × 256, T2-weighted (2000/80) and proton density (2000/20) oblique coronal images with a 16 cm FOV and a 128 × 128 matrix, and fast short tau inversion recovery (STIR) oblique sagittal images (2000/140/18, TR/TI/effective TE) with an 18 cm FOV and a 192 × 256 matrix. A bolus of i.v. Gd-DTPA (0.1 mmol/kg, Magnevist, Berlin, Germany) was administered over a 10–15 s period via an i.v. needle inserted into an antecubital vein, and T1-weighted images were obtained in axial and oblique sagittal directions using otherwise the same parameters as in the pre-contrast scans. Synovial effusion and hypertrophy of the SA-SD bursa, GH joint and BTS, rupture of the biceps tendon, full-thickness tear or intrasubstance abnormality (partial-thickness tear or tendinopathy) of the supraspinatus tendon and erosions on the anteromedial and postero-lateral aspect of the humeral head and on the greater tuberosity were analysed and recorded on the data sheet by the radiologist (OT).

In this study, neither imaging modality was regarded as the ‘gold standard’, and we therefore used kappa coefficients to indicate binary agreement of these methods. The kappa value provides a single summary expression of a 4-fold table of binary concordance between two observers [23]. Values of kappa <0.40 reflect poor agreement, ones between 0.40 and 0.75 fair to good agreement, and ones >0.75 excellent agreement [24]. To resolve the problems of low or increased kappa values due to symmetry imbalance in marginal totals, we used according to Cicchetti and Feinstein [23] positive and negative agreements (p_neg, p_pos) that are analogous to sensitivity and specificity.

RESULTS

The results are shown in Table I with positive and negative agreement and kappa values. Synovial effusion/hypertrophy of the SA-SD bursa was found in 28 shoulders by MRI and in 25 shoulders by US, and it was associated with supraspinatus changes in 24 cases by US and in 27 cases by MRI. Synovial

| Table 1: US and MRI findings with positive and negative agreement and kappa values |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bursa E/H | Biceps R, S, E/H | Synovial effusion | Supraspinatus E/H | Glenohumeral joint E/H | Erosions |
| Identified by MRI | 28 | 11 | 24 | 15 | 13 | 27 | 21 | 21 | 23 |
| — Unidentified by US | 3 | 2 | 5 | 3 | 1 | 4 | 1 | 1 | 5 |
| Identified by US | 25 | 11 | 20 | 13 | 15 | 25 | 28 | 20 | 14 |
| — Unidentified by MRI | 0 | 2 | 1 | 1 | 3 | 2 | 8 | 4 | 0 |
| Identified by MRI & US | 25 | 9 | 19 | 12 | 12 | 23 | 20 | 16 | 14 |
| — Unidentified by MRI & US | 2 | 18 | 6 | 14 | 14 | 2 | 2 | 6 | 8 |
| Positive agreement | 0.94 | 0.82 | 0.86 | 0.86 | 0.86 | 0.88 | 0.82 | 0.78 | 0.76 |
| Negative agreement | 0.57 | 0.90 | 0.67 | 0.87 | 0.87 | 0.40 | 0.31 | 0.57 | 0.64 |
| Kappa | 0.53 | 0.72 | 0.54 | 0.73 | 0.73 | 0.29 | 0.19 | 0.35 | 0.45 |

*E/H, effusion/hypertrophy; R, ruptured; S, E/H, sheath effusion/hypertrophy; FTT, full-thickness tear; ISA, intrasubstance abnormality; GT, greater tuberosity; A-M, anteromedial; P-L, postero-lateral.*
hypertrophy with effusion was revealed within 19 (63%) SA-SD bursae by MRI, indicating synovial inflammation. In seven shoulders evaluated by US, bursal effusion was echogenic, probably including fibrin coagels known to be associated with chronic synovial inflammation.

Biceps tendon rupture was observed in 13 shoulders (in 11 by US and in 11 by MRI), of which 10 were associated with full-thickness tear and three with some other abnormality of the supraspinatus tendon. The agreement of the two imaging modalities on biceps tendon ruptures was good. Effusion/synovial hypertrophy of the BTS was visualized in 24 shoulders by MRI and in 20 by US, and 23 of them were associated with supraspinatus abnormalities. Synovial hypertrophy was shown by MRI to be present in 21 (70%) BTS.

Full-thickness tear of the supraspinatus tendon was found in 15 (50%) shoulders evaluated by MRI and in 13 (43%) by US, and intrasubstance abnormalities of the supraspinatus tendon were revealed in 13 shoulders by MRI and in 15 shoulders by US. Only in two (7%) shoulders was the supraspinatus tendon normal by both modalities. In one shoulder, MRI identified a full-thickness tear located beneath the acromion process that was missed by US. The agreement between these two methods on the changes of the supraspinatus tendon was good.

Effusion/synovial hypertrophy of the GH joint was evaluated in 27 shoulders by MRI (four of them were normal by US) and in 25 by US (two of them were normal by MRI). Effusion/hypertrophy of the GH joint detected by US or MRI was associated with rotator cuff disorders in 27 of the 30 evaluated shoulders.

Most patients had erosions on their humeral head. The distribution of the erosions detected by US and MRI was different: US showed erosions on the greater tuberosity in 28 and MR in 21 shoulders. MRI depicted erosions on the lateroposterior aspect of the humeral head in 23 and US in 14 shoulders. Positive agreement was high, but the values of kappa reflected poor to fair agreement.

**DISCUSSION**

In the past 10 yr, US and MRI have been introduced into the clinical practice of diagnosing shoulder problems, especially in soft-tissue manifestations. Although MRI is superior to US in depicting the extent of granulation tissue, effusion and rotator cuff pathology, is less operator dependent and shows intraosseous pathology, it is less available because it is expensive, time consuming and less convenient to the patients [20].

MRI showed effusion/hypertrophy within the SA-SD bursa in three shoulders that were missed by US. Although these patients had rotator cuff disorders (two full-thickness tears and one intrasubstance abnormality of the supraspinatus tendon), we did not see bursal effusion in US, and MRI only showed small amounts of fluid and in two shoulders also mild synovial hypertrophy within the SA-SD bursa. An interesting question is: what is the effect of gravitation on bursal effusion in full-thickness rotator cuff tears in the sitting position during US evaluation or in the supine position during MRI scanning. Earlier studies have shown that MRI can depict fluid within the SA-SD bursa of 20% of healthy subjects [25], but sonographic findings of isolated bursal effusion are uncommon [6]. This discrepancy between MRI and US appears to be caused by the greater conspicuousness of scant amounts of fluid in MRI, sonographic obscuration of fluid located exclusively within the subacromial bursa beneath the acromion [6] or the failure of sonography to detect fluid with internal echoes [14].

The SA-SD bursa and the supraspinatus tendon of one patient were not evaluable by MRI because the examination was interrupted by claustrophobia.

The empty bicipital groove is only seen in cases of acute biceps tendon rupture, as amorphous tissue (granulation and fibrous tissue) fills the groove after rupture [26]. This amorphous tissue causes difficulties in both the US and the MRI evaluation of the biceps tendon rupture because it imitates the biceps tendon in the bicipital groove. This problem was also apparent in our study; two biceps tendon ruptures were visualized by US, but not by MRI, and two tendon ruptures by MRI but not by US.

There were some difficulties in differentiating partial-thickness tear from tendon degeneration both in US and MRI examinations, and we therefore used the term ‘intrasubstance abnormality’ [27] to represent both changes of the supraspinatus tendon. Consistent differentiation between partial-thickness tears, tendinitis and tendon degeneration is difficult at MRI [28–30]. Histological data of rotator cuff lesions with increased signal intensity on MR images have shown no evidence of active inflammation, but rather tendon degeneration [28, 31].

Many published reports emphasize the accuracy of shoulder sonography for detecting rotator cuff tears when it is performed by dedicated experts [1, 10, 13, 22, 32], but less favourable results have also been reported [33]. MRI has been considered as the best method to detect rotator cuff tears [34]. However, MRI criteria for the diagnosis of a tear are not universally accepted [29]. Overall, MRI seems to be somewhat superior to US for the diagnosis of rotator cuff tears. In our study, MRI revealed two full-thickness tears that were interpreted by US as intrasubstance abnormality according to the mixed hyper- and hypoechogenicity of the tendon. The presence of echogenic foci within the rotator cuff might be full-thickness tears filled with granulation tissue and proliferated bursal elements, as described earlier [10]. If a rotator cuff tear is located beneath the acromion, it is invisible by US [22]. One tear was missed in this way by US. One full-thickness tear depicted by US was interpreted as intrasubstance abnormality by MRI.

In rheumatoid arthritis, synovial inflammation causes rotator cuff lesions and erosions on the greater tuberosity; however, in older persons, these changes may also be caused by degeneration [35]. In all the 16 shoulders with rotator cuff tear, there were erosions on
the greater tuberosity shown by US. The mean age of our patients was rather high, thus the lesions found may be a mixture of degenerative and inflammatory changes.

In this study, kappa coefficients were used to indicate binary agreement of the imaging methods. The kappa coefficient is proposed for use as an index of validity, association or reliability, when investigators are testing observer variability [36]. US and MRI had a high agreement on biceps tendon ruptures and rotator cuff disorders, a rather good agreement on effusion/hypertrophy of the SA-SD bursa or BTS, but a poor agreement on erosions or joint effusion/hypertrophy. Positive and negative agreements were used to resolve problems with low kappa values. In the present study, with good or high kappa values positive and negative agreements were also high. In cases with low kappa values, positive agreement was high, reflecting good sensitivity, and negative agreement was fair or good, reflecting fair or good specificity.

The study was carefully planned and prospective. However, some criticism is apparent. Only a static examination was performed by US routinely; a dynamic examination could have given more information on the supraspinatus tendon and the SA-SD bursa in the cases with different findings on US and MRI scans.

On the basis of this study, we conclude that US and MRI findings of the shoulders of patients with chronic arthritis are relatively consistent. However, we have to take into account the limitation that, generally, US does not differentiate synovial hypertrophy from effusion. In depicting rotator cuff tears, MRI was better than US. When assessing the reliability and suitability of US evaluation in rheumatology, however, the diagnostic accuracy is good enough. The low costs, safety and wide availability of US scanners favour their use in the evaluation of joint disorders.

References
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