

## EVALUATION OF HUMERAL HEAD EROSIONS IN RHEUMATOID ARTHRITIS: A COMPARISON OF ULTRASONOGRAPHY, MAGNETIC RESONANCE IMAGING, COMPUTED TOMOGRAPHY AND PLAIN RADIOGRAPHY

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### SUMMARY

The value of ultrasonography (US), magnetic resonance imaging (MRI), computed tomography (CT) and plain radiography (PR) in detecting bone erosions on the humeral head was evaluated in a study of 26 in-patients (26 shoulders) with rheumatoid arthritis (RA). MRI depicted humeral erosions in 25 (96%), US in 24 (92%), CT in 20 (77%) and PR in 19 (73%) of the 26 shoulders. MRI and US were superior to CT in detecting small erosions. US was the most sensitive method to show surface erosions on the greater tuberosity. US, CT and MRI detected large erosions quite similarly. PR frequently missed small erosions. In the evaluation of early erosions in the rheumatoid shoulder, US and MRI are more sensitive methods than the traditionally used PR. US and MRI are suitable for the evaluation of soft-tissue involvement in the rheumatoid shoulder, but also for the detection of bone erosions of the humeral head.

**KEY WORDS:** Rheumatoid arthritis, Glenohumeral joint, Erosion, Ultrasonography, Magnetic resonance imaging, Computed tomography, Radiography.

THE shoulder joint becomes involved later than the peripheral joints in rheumatoid arthritis (RA). However, during the first 2 yr of rheumatoid history, nearly 50% of patients have shoulder symptoms [1]. The onset of the disease in the shoulder joint is often insidious. Inflammatory changes and damage to the tissues of the shoulder joint may already be visible by ultrasonography (US) or magnetic resonance imaging (MRI) at the time when the clinical examination or plain radiographs are still quite normal [2–4]. Radiographic assessment has served as an objective standard for the evaluation of RA progression. The development of radiographic joint damage is well known in the hands and feet, whereas data on shoulder joints are scarce [5].

US has been found to be superior to plain radiography (PR) in the detection of bone erosions [6], new bone formation [7] and occult fractures [8]. In the rheumatoid shoulder, MRI can depict both soft-tissue and bone changes that are not clearly seen on radiographs and are impossible to evaluate by clinical examination [4, 9]. Apart from bony erosions, MRI also shows cartilage damage and intraosseus abnormality [4, 9]. Computed tomography (CT) of the glenohumeral (GH) joint can also reveal bone erosions [10] and, in RA, is noted to be superior to PR in depicting subchondral and intraosseus bone lesions [11].

The aim of this study was to determine the ability of US, CT, MRI and PR to depict erosions on the humeral head.

### MATERIALS AND METHODS

Twenty-six patients with a painful shoulder and a confirmed diagnosis of RA [12] were selected from the

rheumatology ward and examined by US, CT, MRI and PR. This group included 20 women and six men with a mean age of 62 (range 40–83) yr. Nineteen patients had seropositive, six seronegative and one seropositive juvenile RA. The mean duration of the disease was 12 yr (range 1 month–42 yr) and the mean duration of shoulder symptoms was 4 yr (range 1 month–20 yr).

All of the imaging modalities were performed on the same day. The investigators who performed US, CT and MRI were blind to the results obtained with the other methods. The erosions on the lateral (including greater tuberosity), anteromedial (including minor tuberosity) and posterior aspects of the humeral head were analysed by all methods and recorded on the data sheets.

At first, US (7.5 MHz linear array transducers, Aloka SSD-650 and Aloka 2000, Tokyo, Japan) was performed by two authors together, who were experienced in shoulder sonography (EA, a rheumatologist, and RT, a radiologist). The final US result was determined by consensus. The whole shoulder girdle was examined, and the findings concerning the surface changes of the humeral head were recorded for this study. The head of the humerus was carefully scanned to detect the presence of any erosion: anteriorly in maximal outward rotation, laterally in hyperextension and internal rotation, posteriorly in adduction and internal rotation with the hand clasping onto the opposite shoulder, in the axilla (medially) with the humerus in 90° abduction and also with continuous monitoring of the humeral head during shoulder movement. Marginal bone erosions and bone irregularities of the humeral head were recorded as follows: (1) small circumscribed erosion (could also consist of two small erosions), (2) superficial erosion (= rough bone surface) or (3) large circumscribed erosion (could also consist of multiple confluent erosions).

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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) 16 cm and a matrix of  $256 \times 256$ , T2-weighted (2000/80) and proton density (2000/20) oblique coronal images with a 16 cm FOV and a  $128 \times 128$  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  $192 \times 256$  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, otherwise using the same parameters as in the pre-contrast scans. 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 a radiologist experienced with MRI (OT).

CT (GE HiSpeed Advantage, General Electric Medical Systems, Milwaukee, WI, USA) of the shoulder was performed with the patient lying supine and the hands down the sides of the body. A 2 s scan time, 3 mm contiguous axial scans at 140 kV/300 mA and a standard algorithm were applied in most cases. The ordinary axial scans and any multiplanar reformats useful for the interpretation of the findings were printed on film. The presence of erosions was analysed by a radiologist experienced with CT (SL).

Two antero-posterior radiographs were obtained from the shoulder with the patient seated against the cassette and turned slightly toward the imaged side: one with the patient's arm in internal rotation and the other with the arm in external rotation. Additionally, a lateral oblique radiograph was obtained with the patient facing the film and the opposite shoulder turned until the broad plane of the scapula was at an angle of 75–80° to the film. The erosions of the humeral head were analysed by a radiologist (OT). The radiographic joint damage was also assessed according to Larsen grades (0–V) [13] as follows: grade 0, normal; grade I, slight abnormality: periarticular osteoporosis, periarticular soft-tissue swelling and slight joint space narrowing; grade II, definite abnormality: joint space narrowing and/or small erosions; grade III, marked abnormality: erosions and joint space narrowing in all cases; grade IV, severe abnormality: the original articular surfaces partly preserved; grade V, mutilating abnormality: no original articular surfaces preserved, gross deformity.

## RESULTS

MRI detected erosions in 25 (96%), US in 24 (92%), CT in 20 (77%) and PR in 19 (73%) of the 26 shoulders. There were four GH joints with Larsen grade 0, five with grade I, 12 with grade II, four with grade III and one with grade IV. US and MRI depicted erosions in

three and CT in one of the four shoulders with Larsen grade 0. US and CT showed erosions in four and MRI in all of the five shoulders with Larsen grade I. Figure 1 shows humeral head erosions in one shoulder as illustrated by all four methods.

Most of the erosions were found on the lateral aspect of the humeral head (Table I), i.e. on the greater tuberosity, and were superficial. In this area, US showed a larger number of bone erosions (in 22 shoulders) than MRI (in 19 shoulders), CT (in 15 shoulders) or PR (in 15 shoulders). MRI depicted more erosions than the other methods on the antero-medial (in 18 shoulders) and postero-lateral (in 20 shoulders) aspects of the humeral head, and in these two areas PR was able to show erosions in six shoulders. On the postero-lateral aspect of the humeral head, US and CT detected erosions in only 10 and six shoulders, respectively. MRI showed significantly more small erosions in all areas, and US on the greater tuberosity and the postero-lateral aspect of the humeral head, compared with CT and PR. US, MRI and CT detected large erosions quite similarly. In three shoulders, a large erosion zone surrounding the anatomical neck of the humerus was observed uniformly in all four modalities.

The congruence between US and MRI in the detection of erosions was quite good in the greater tuberosity and in the anteromedial region, but in the postero-lateral region MRI showed much more erosions than US (Table II). US and MRI depicted more erosions than CT and especially more than PR. CT showed more erosions than PR in the anteromedial region, but in the postero-lateral region both CT and PR depicted only a few erosions. There were some cases in which only one method showed erosions: MRI showed erosions in the postero-lateral region in nine shoulders; US, MRI and CT showed erosions in the anteromedial region in one shoulder each; and US showed erosions on the greater tuberosity in one shoulder. The congruence of the results obtained by all four methods was moderate: in 54% of the shoulders on the greater tuberosity, in 38% on the anteromedial aspect and in 42% on the postero-lateral aspect of the humeral head.

## DISCUSSION

Beyond shoulder symptoms and signs, we have had little knowledge of the early inflammatory changes in the shoulder, because the evidence of rheumatoid involvement of the shoulder has been mainly based on plain radiographic assessment. The radiographic scoring methods are based on the presence of bone erosions, joint space narrowing, osteoporosis, subluxation, ankylosis, malalignment, cysts and sclerosis [13–17]. The early development of radiographic joint damage is well known in the peripheral joints (in ~75% of RA patients during the first 2 yr of the disease) [3, 5], whereas data on shoulder joints are scarce [5]. Later on, the progression of RA has been found to be correlated quite well in the peripheral and large joints [18]. Radiographic damage to the shoulder joint has been noticed within 6 yr of disease duration in >50%



FIG. 1.—Erosions on the same humeral head as illustrated (a) by US (arrows show the erosion), (b) by MRI, (c) by CT and (d) by PR.

TABLE I

Number of shoulders (= patients) in which erosions were seen or not seen by US, CT, MRI and PR on the greater tuberosity (GT) and the anteromedial (A-M) and postero-lateral (P-L) aspects of the humeral head. The results are also grouped according to the size of the erosion

Site	Erosions	US	CT	MRI	PR
GT	Total number	22	15	19	15
	Small	3	1	7	1
	Superficial	11	8	5	9
	Large	8	6	7	5
	No erosion	4	11	7	11
A-M	Total number	16	14	18	6
	Small	3	2	10	2
	Superficial	8	8	4	2
	Large	5	4	4	2
	No erosion	10	12	8	20
P-L	Total number	10	6	20	6
	Small	3	0	12	1
	Superficial	3	2	4	2
	Large	4	4	4	3
	No erosion	16	20	6	20

of RA patients [19] and after a disease duration of 19 yr in 64% of RA patients [20]. In the present study, the mean duration of RA was 12 yr, and erosions were visualized in 73% by PR, in 92% by US, in 77% by CT and in 96% of the shoulders by MRI. Overall, MRI and US detected erosions in the rheumatoid shoulder more often and earlier than PR.

Erosive changes seem to occur most frequently on the superolateral aspect of the humeral head [21, 22]. In RA, synovial inflammation causes rotator cuff lesions and erosions on the greater tuberosity, but in older people such changes may also be caused by degeneration [23]. In the present series, most erosions were found on the greater tuberosity and many also on the lesser tuberosity, i.e. at the sites of insertion of the rotator cuff, and US depicted more erosions than the other methods in these areas. The accuracy of US in depicting even minor bone surface changes and periosteal changes has been demonstrated in other studies [7, 8], and our study clearly indicates that high sensitivity can be achieved by this method in detecting superficial erosions. However, because the mean age of our patients was fairly high, some of the lesions

TABLE II

Numbers of shoulders (= patients) in which erosions were seen or not seen by MRI vs US, by US vs CT, by US vs PR, by MRI vs CT, by MRI vs PR and by CT vs PR on the greater tuberosity (GT) and the anteromedial (A-M) and postero-lateral (P-L) aspects of the humeral head. The results are also grouped according to the number of shoulders in which erosions were found by one method more, equally or less well compared with the other method

Site	MRI vs US				US vs CT				US vs PR			
	More	Equal	Less	NE	More	Equal	Less	NE	More	Equal	Less	NE
GT	1	18	4	3	8	14	1	3	7	15	0	4
A-M	3	15	1	7	4	12	2	8	11	5	1	9
P-L	10	10	0	6	4	6	0	16	5	5	1	15

  

Site	MRI vs CT				MRI vs PR				CT vs PR			
	More	Equal	Less	NE	More	Equal	Less	NE	More	Equal	Less	NE
GT	6	13	2	5	5	14	1	6	4	11	4	7
A-M	5	13	1	7	12	6	0	8	10	4	2	10
P-L	14	6	0	6	14	6	0	6	1	5	1	19

NE, no erosions by either method.

found may be a faint congruence of degenerative and inflammatory changes.

Owing to its physical and acoustic properties, US is capable of revealing only bone surface changes [24]. Therefore, the most superior aspect of the humeral head beneath the acromion and the glenoidal part of the scapula are invisible in US. If the shoulder anatomy has been altered and arm movements are restricted, visualization of the shoulder structures may be inadequate by US [25].

MRI detected more erosive lesions than the other imaging methods, both in general and in comparison with US, in particular, in the postero-lateral region. The high sensitivity of MRI in depicting bone marrow changes has been confirmed in many reports when MRI has been compared with CT [26, 27]. Nevertheless, the lesions defined as erosions in MRI in this study, especially in the postero-lateral region, might not be true erosions, but pre-erosive oedematous changes in subchondral bone. The MRI criteria of erosions used in this work—subcortical areas of high signal intensity in T2-weighted images and low signal intensity in T1-weighted images—do not reflect directly the change in the bone matrix, but rather the change in the fat/water ratio of the bone marrow. The MRI finding representing a loss of bone due to an erosive process is homogeneous high intensity similar to fluid. This finding can be accurately determined in large erosions, but in lesions <2 mm in diameter, signal intensity may vary due to a partial volume effect.

One important finding of this study was the discrepancy between the different modalities in detecting small erosions, MRI and US being superior to CT. The sensitivity of MRI is mainly due to the high contrast discussed above. The sensitivity of US is, however, due to the better spatial resolution of the method. The practical resolution of US employing a 7.5 MHz probe in the imaging of superficial structures is of the order of 0.3–0.6 mm, while the resolution of CT is of the order of 1.0–1.3 mm, using a slice thickness of 3 mm and FOV of 16 cm, as in this study. The accuracy of

US in depicting even minor bone surface changes and periosteal reactions was mentioned above. Some problems with CT may appear when a curvilinear object is examined. The more the reformat plain parallels the z-axis, the more the resolution of multiplanar reformats is impaired. The partial volume effect is harmful in CT. In addition, the shoulder, being situated in the thickest part of the body, is the least accessible region for CT due to the image noise not compensated for even by high kV/mA values.

US proved to be much more sensitive than PR in detecting erosions. A plain radiograph is a projection image, and though we used two projections in this study, there were significant areas on the anterior and posterior aspects of the humeral head which were not accurately covered. These were also the areas where US was especially more sensitive than PR. The difference was not so remarkable on the greater tuberosity, which can be more accurately evaluated in PR due to the shape and anatomical location of this area. It should be noted that no imaging method was regarded here as the 'gold standard' and, therefore, information on the specificity of the findings obtained by the different imaging modalities is lacking.

Our study shows that US and MRI are able to pick up humeral erosions earlier than PR, i.e. in shoulders with Larsen grades 0 and I. MRI is more sensitive in depicting small erosions than US, probably due to it also detecting pre-erosive changes. US depicts large erosions equally well as MRI and CT. CT is able to detect large erosions, but it depicts small erosions poorly. Information gained by PR is dependent on the projections used and is therefore limited. Thus, PR misses a lot of erosions. US and MRI are not recommended merely to evaluate erosive changes of the GH joint, but while screening for rheumatoid involvement of the shoulder by US or MRI, the erosiveness of the disease can be assessed at the same time.

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