Bone destruction, upward migration, and medialisation of rheumatoid shoulder: a 15 year follow up study

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Abstract
Objective—To evaluate bone destruction, upward migration, and medialisation of the glenohumeral (GH) joint in a cohort of 74 patients with seropositive and erosive rheumatoid arthritis followed up prospectively.
Methods—At the 15 year follow up 148 shoulders were radiographed by a standard method. Bone destruction in the GH joint was examined from the radiographs by four methods, of which three measured the migration and one the remodelling of the humeral head. The distances from the greater tuberosity of the humeral head to the coracoid process (medialisation distance (MD)) and to the articular surface of the humeral head (GA) have been previously developed to evaluate the pre-operative offsets of the arthritic GH joint. Medial displacement index (MI) and upward migration index (UI) have been recently developed to evaluate the destructive pattern of the rheumatoid GH joint. Destruction of the GH joints was assessed by the Larsen method on a scale of 0 to 5. The relation between the measurements and the grade of destruction of the GH joints was examined. UI was compared with our previous measurements of the subacromial space.
Results—Both the MI and the UI had a negative correlation with the GH joint destruction (Larsen grade), $r=-0.49$ (95% CI -0.36 to -0.60) and $r=-0.58$ (95% CI -0.46 to -0.68). The UI correlated significantly with the subacromial space, $r=0.90$ (95% CI 0.86 to 0.93). The mean MI and UI measurements of the non-affected joints were within the reported normal variation. The mean MD collapsed between Larsen grades 4 (83.0 mm) and 5 (65.5 mm). The morphology of the humeral head began to flatten and erode from the grade 3 onwards and medial head destruction was detected at grade 5.
Conclusions—Medialisation seems to be preceded by upward migration of the humeral head, indicating rotator cuff damage. Symptomatic Larsen grade 3 shoulders should be intensively followed up by clinical and radiological means. If a total shoulder arthroplasty is considered, an orthopaedic consultation is worthwhile at a sufficiently early stage (Larsen 3 and 4), when soft tissue structures responsible

for function are still in proper condition and timing of the operative procedure can be well planned.
(Ann Rheum Dis 2001;60:322–326)

Most (67–91%) patients with rheumatoid arthritis (RA) have shoulder pain, and more than one in five present moderate or severe glenohumeral (GH) joint destruction during the first 15 years from the disease onset.^{1–3} Continuous plain radiographs of the rheumatoid shoulder are the primary diagnostic means of evaluating the glenohumeral joint and planning shoulder arthroplasty.^{4–6} Medial migration and remodelling of the humeral head with medialisation of the GH joint due to bone destruction are common radiographic findings in rheumatoid arthritis (RA).^{4–13} As far as we know, no previous studies have thoroughly measured the relation between GH joint destruction and upward migration and medialisation of the humeral head in patients with RA. This study aimed at analysing the upward migration and medialisation of the humeral head and their relation to rheumatoid destruction of the GH joint in an inception cohort study of 74 patients with RA followed up for 15 years.

Materials and methods
During the period 1973–75 a total of 121 patients with recent (≤ 6 months) RA were studied at the Rheumatism Foundation Hospital, Heinola, Finland. The selection criteria, data collection strategy, and details of the patients have been described elsewhere.^{14–15} At the three year follow up 102 patients had rheumatoid factor positive, erosive RA. Subsequently, 24 patients died and four patients failed to attend the 15 year follow up. Thus 74 patients (18 men, 56 women) were the subjects of this study; their age at onset ranged from 17 to 66, mean 42 (SD 12) years. Radiographs of all the 148 shoulders were taken at the 15 year follow up as part of a radiographic survey study. The following standard positioning was used: patient supine, turned 20° to the imaged side, and the arm in external rotation, palm facing upwards. The same trained radiographer confirmed correct positioning and took x ray pictures by the standard technique: the straight (central beam 90° towards the GH joint) anteroposterior projection (distance 0.95 m) was used with exposure factors of 48 kV and -63 mA. The

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Accepted 29 August 2000

Figure 1 (A–D) Illustration of the measurement methods used in this study. (A) Medialisation distance (MD); (B) upward migration index (UI); (C) medial displacement index (MI); (D) greater tuberosity-articular surface distance (GA). See “Materials and methods” section for further details.

size of the film (Kodak Lanex Regular) was 18×24 cm.

Destruction of the glenohumeral joints was assessed by the Larsen method on a scale of 0 to 5.¹⁶ One shoulder arthroplasty was performed 13 years after onset of the disease, and in this case the preoperative radiograph (Larsen grade 5) was assessed and measured.

Medialisation (MD) of the GH joint was measured as the distance from the lateral aspect of the greater tuberosity to the medial margin of the coracoid process as described by Figgie *et al* (fig 1A).¹⁷ The upward migration index (UI) was obtained by dividing the distance between the centre of the humeral head and the central point of the subacromial surface (U) by the radius of the humeral head (R) (fig 1B).¹⁸ The medial displacement index (MI) was obtained by dividing the distance between the centre of the humeral head and the glenoid surface (M) by the radius of the humeral head (R) (fig 1C), as described by Hirooka *et al*.¹⁸ The position of the centre of the humeral head was determined with a circle fitting technique. In shoulders with destruction the bony morphology, the radius of the humeral head, and the original glenoidal and subacromial surfaces were confirmed and measured from the earlier radiographs. Subacromial space measurements from our previous study were compared with the UI.¹⁹ The

perpendicular distance from the superior aspect of the greater tuberosity to the superior articular surface (GA) was measured (fig 1D), as illustrated by Figgie *et al*.¹⁷

Statistical comparison between shoulders with different grades of destruction was performed using analysis of variance (ANOVA). Correlations were estimated by Pearson's and Spearman's coefficients. The normality of continuous variables was evaluated by the Kolmogorov-Smirnov statistics with a Lilliefors significance or Shapiro-Wilk statistics. No adjustment was made for multiple testing.

Results

There was no systematic right-left difference in any of the measuring methods in either sex, and therefore the measurements of the two sides were pooled. Table 1 shows the distribution of the GH joints (n=148) according to the Larsen grading and the mean measurements of destruction in each group, as well as ANOVA statistics models.

The diminution of the MI between different grades of destruction showed a significant trend ($p<0.001$). The correlation coefficient between MI and Larsen grading was -0.49 (95% CI -0.36 to -0.60). The MI correlated also with the MD, $r=0.53$ (95% CI 0.40 to 0.64), though the medialisation occurred late

Table 1 Radiographic assessment of 148 glenohumeral (GH) joints according to the Larsen grading and the mean medialisation distance (MD), medial displacement index (MI), upward migration index (UI), and greater tuberosity-articular surface (GA) measurements for each group

Larsen grade	Number of GH joints (%)	MD, mm (mean, SD)	MI (mean, SD)	UI (mean, SD)	GA, mm (mean, SD)
0	33 (22)	85.4 (6.3)	0.90 (0.04)	1.27 (0.06)	6.8 (1.7)
1	44 (30)	81.2 (6.6)	0.88 (0.04)	1.24 (0.09)	6.3 (1.7)
2	40 (27)	87.9 (8.2)	0.87 (0.05)	1.20 (0.08)	6.8 (1.5)
3	14 (9)	85.6 (8.1)	0.84 (0.08)	1.16 (0.14)	6.1 (2.3)
4	6 (4)	83.0 (4.9)	0.71 (0.07)	0.97 (0.14)	4.7 (1.6)
5	11 (7)	64.5 (8.5)	0.49 (0.15)	0.82 (0.16)	2.9 (3.3)
Total	148 (100)	83.2 (9.3)	0.84 (0.12)	1.19 (0.15)	6.2 (2.1)
ANOVA*	p Values between: Different Larsen groups Linearity of destruction Eta coefficient	<0.001 <0.001 0.64	<0.001 <0.001 0.87	<0.001 <0.001 0.78	<0.001 <0.001 0.49

*ANOVA = analysis of variance.

($p<0.001$) and had no significant correlation with Larsen grading. The mean MI of the non-affected joints (Larsen grades 0 and 1) was 0.89 (SD 0.04). The mean MD of the non-affected joints was 83.0 (SD 6.7) mm. The diminution of the UI between increasing grades of destruction had a significant trend ($p<0.001$). The correlation coefficient between UI and Larsen grading was -0.58 (95% CI -0.46 to -0.68). A remarkable correlation occurred between the subacromial space and UI, $r=0.90$ (95% CI 0.86 to 0.93). The mean UI of the non-affected (Larsen grade 0 and 1) joints was 1.26 (SD 0.08). The GA also decreased with increasing destruction ($p<0.001$). There was a slight correlation between GA and Larsen grading, $r=-0.29$ (95% CI -0.14 to -0.43). However, it had no significant correlation with either upward migration index or subacromial space measurements.

Discussion

The results of this study confirm the visually observed medialisation in radiographs of rheumatoid shoulder.^{4 7 10-12} The mean distance from the lateral aspect of the humeral head to the coracoid process collapsed between Larsen grades 4 and 5 (figs 2 and 3). The medial displacement index (MI) takes into account the size of the bones of the patient by dividing the medial distance by the radius of the humeral head (fig 1C).¹⁸ It shows more precisely that medialisation is evident already between Larsen grades 3 and 4, before the remarkable reduction between grades 4 and 5 occurs. The mean MI of the non-affected GH joints was within 2SD of the mean of normal controls, as measured by Hirooka *et al.*¹⁸ An MD <70 mm (mean of non-affected joints $-2SD$) could be considered as a sign of definite medialisation of the GH joint when evaluating a shoulder radiograph taken at 0.95 mm distance. The UI correlated well with the subacromial space measurements, emphasising our previous results for the rotator cuff involvement in the rheumatoid shoulder.¹⁹ The mean UI of the non-affected GH joints was within 2SD of the mean of normal controls, as measured by Hirooka *et al.*¹⁸ The previous subacromial space measurements of the non-affected joints

were also normal.^{19 20} Although upward migration of the humeral head seems to be an inevitable consequence of rheumatoid affection, there seems to be an evident step in rotator cuff involvement during the course of GH destruction in RA.¹⁹ Medialisation of the GH joint seems to be slightly preceded by superior migration of the humeral head according to our results (fig 2) and as reported previously.^{7 12 19} However, if the concavity of the superior glenoidal articular surface is destroyed by erosions, the resultant force from the deltoid and theoretically intact rotator cuff can pull the humeral head into superior subluxation.²¹ Computed tomography measurements have shown that the medial displacement of the glenoid surface was greatest at the upper and middle levels: the surface was inclined superiorly rather than inferiorly.²² Yet, at the time of

Figure 2 Radiograph of a rheumatoid shoulder. Extensive erosive destruction on the articular margins, leaving part of the original articular surface still intact (Larsen 4). Evident superior migration of the humeral head is present and the joint space has disappeared. However, there is no evident medialisation of the humeral head.

Figure 3 Radiograph of a rheumatoid shoulder. Gross bone destruction of the humeral head has occurred (Larsen 5). Superior and medial migration of the humeral head have occurred and remarkable loss of the glenoid bone stock is present.

arthroplasty, attenuation or tearing of the rotator cuff is more often found than glenoid destruction, when superior migration of the humeral head is present.^{10 23 24}

The commonly described flattening of the humeral head in rheumatoid shoulder is supported by the diminution of the distance between the greater tuberosity and the superior articular surface (GA).^{8 9 25} Flattening is evident in Larsen grade 3 and more obvious in grades 4 and 5, when the superior humeral head is almost even (figs 2 and 3). However, flattening had no correlation with decreasing subacromial space and UI, suggesting that it is not caused by friction with the inferior acromion. This finding is probably caused by erosive destruction, which is more common on the superior joint margin of the humerus.^{2 7 8}

Shoulder arthroplasty yields excellent pain relief for the painful rheumatoid shoulder.^{24 26} However, the improvement in range of motion and function lag far behind that routinely expected after hip and knee replacements.²³ Restoration of normal glenoid and humeral anatomy in the arthroplasty is correlated with diminished radiographic loosening as well as improved functional results.¹⁷ Larsen grades 4 and 5, and sometimes grade 3, have been widely used as radiological indications for shoulder arthroplasty.^{10 13} An interesting finding is the collapse of the medialisation distance when GH destruction reaches the Larsen grade of 5 (fig 3). A similar phenomenon occurred with the subacromial space between grades 3 and 4 (fig 2).¹⁹ Rapid upward migration has been considered as a sign of rapid destruction of the rheumatoid shoulder, therefore early surgical intervention is recommended for these

patients.^{7 27 28} Our results support these findings; upward migration is followed by medialisation and gross destruction of the GH joint, which most often is the preoperative state of unsuccessful arthroplasties.

In clinical practice symptomatic Larsen grade 3 shoulders with persisting synovitis should be monitored carefully and the result of conservative treatment should be evaluated regularly. When symptoms continue and radiographic findings are progressive, operative treatment should not be delayed, because destruction may develop beyond the possibility of adequate repair. We emphasise that those patients with RA, who have glenohumeral erosions and a sign of upward migration of the humerus on a plain radiograph (fig 2), should be candidates for a rapid orthopaedic consultation and advanced soft tissue imaging like ultrasound or magnetic resonance arthrography.

Overall functional results of the arthroplasty are related to the physical condition as well as the motivation of the patient and the status of the rotator cuff.^{17 24} Total shoulder arthroplasty will not survive without sufficient glenoid bone stock and neither will it function properly without adequately preserved soft tissue structures.²⁷ An orthopaedic consultation is worthwhile at a sufficiently early stage (Larsen 3 and 4), so that timing of the operative procedure can be well planned.

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