Rotator cuff degeneration in the rheumatoid shoulder : 'the issue is soft tissue'

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Chapter 4

The relation between CT based fatty degeneration of the rotator cuff muscles and proximal migration of the humeral head on AP radiographs

Subacromial space measurement: A reliable screening method indicating fatty degeneration

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Summary

Proximal migration of the humeral head is thought to indicate fatty infiltration of the rotator cuff muscles or rotator cuff tears. We sought to evaluate the influence of these rotator cuff abnormalities on the subacromial space. Using anteroposterior radiographs, ultrasound, and computed tomography, we analyzed 54 shoulders in 29 patients with rheumatoid arthritis. The upward migration index was defined as proximal migration of the humeral head relative to its size. The mean muscle density from computed tomography images was used to indicate fatty infiltration. Fatty infiltration of the Infraspinatus muscle showed the strongest correlation with proximal migration. After correcting for age, cuff tears, and rheumatoid disease, the partial correlation coefficient between both remained strong. A subdivision in proximal migration is proposed to screen for rotator cuff abnormalities. A large amount of fatty infiltration was indicated by an upward migration index less than 1.25, a medium amount by an upward migration index between 1.25 to 1.35, and a small amount by an upward migration index greater than 1.35. Measurement of proximal migration using the upward migration index provides a reliable screening method indicating fatty infiltration of the rotator cuff.

Introduction

The severity of rotator cuff abnormalities (fatty infiltration of the rotator cuff muscles and rotator cuff tears) has a negative effect on the outcome of shoulder surgery.[1; 7; 15; 81; 119; 121] Fatty infiltration and rotator cuff tears lead to a greater risk of surgical failure and are associated with inferior functional results after tendon repair and shoulder arthroplasty.[1; 15; 81] Some authors suggest fatty infiltration does not diminish after rotator cuff repair and it seems irreversible.[12; 15] This implies the importance of timely diagnosis and treatment.[161] Magnetic resonance arthrography (MRA) is considered the gold standard in diagnosing rotator cuff tears; however, tears also can be diagnosed using musculoskeletal magnetic resonance imaging (MRI), ultrasound, or computed tomography arthrography (CTA).[5; 162] These diagnostic tools, including MRA, all are relatively expensive, time consuming, depend on the radiologist's experience, or require invasive techniques, such as contrast injection or radiation, which makes them less practical in screening and follow-up studies. Simple measurement of subacromial space narrowing based on plain shoulder radiographs to determine Supraspinatus tendon ruptures have been described.[33-35] Proximal migration of the humeral head has been indicative of a rotator cuff tear, but not diagnostic.[13; 36-39] Goutallier et al presumed a relationship between fatty infiltration of the rotator cuff muscles and proximal migration of the humeral head.[15] This was supported by Nove-Josserand et al, who reported a strong correlation between decreased subacromial space and fatty infiltration or the presence of rotator cuff tears.[163] However, using an absolute measure for the

acromiohumeral interval and a visual score for the amount of fatty infiltration[17] made it difficult to present a reliable cut-off value indicating rotator cuff disease. One study showed a relative measure (dividing the distance from the center of the humeral head to the undersurface of the acromion by the radius of the humeral head[13]) proved much more accurate and reliable in measuring the subacromial space, compared with the absolute measure of the acromion-humeral interval.[148] Assessing fatty infiltration has been described using a visual score according to Goutallier et al. [8] However, their score is only moderately reproducible and requires experienced observers, and separately evaluating each muscle is less reliable.[15; 17] We introduced a quantitative technique using CT images to calculate the mean muscle density as a measure of fatty infiltration.[143] This technique produced a greater interobserver reliability compared with the score of Goutallier et al. Our first hypothesis was that fatty infiltration of the rotator cuff muscles causes a decrease of the acromiohumeral interval, more so than other patient-related factors such as age, shoulder complaints, or the presence of a rotator cuff tear. The secondary hypothesis was that fatty infiltration of the Infraspinatus and Teres Minor muscles (shoulder depression) primarily is responsible for proximal migration of the humeral head. The third hypothesis was that a cut-off-point for proximal migration can be used to screen for rotator cuff abnormalities such as fatty infiltration.

Materials and methods

In patients with rheumatoid arthritis and shoulder complaints we obtained an anteroposterior (AP) radiograph, CT scan, and ultrasound of both shoulders were done to assess the relationship between proximal migration, fatty infiltration, and the presence of a rotator cuff tear. A power analysis suggested a sample size of 59 shoulders would achieve 81% power using an F test to detect a slope of 0.07 when the standard deviation of the amount of fatty infiltration is 0.60, the standard deviation of proximal migration is 0.12, and the significance level is 0.05. The actual standard deviations for both measurements were much smaller (0.45 and 0.07), therefore fewer shoulders were needed to achieve an equal power. Between January 2003 and July 2004, we included 29 consecutive patients with rheumatoid arthritis (54 shoulders). Patients were included after their treating physician ordered bilateral AP radiographs to assess shoulder complaints. Final inclusion was based on the following criteria: (1) clinically diagnosed with rheumatoid arthritis (RA) according to the American Rheumatism Association criteria 1987 as having rotator cuff disease (eg, rotator cuff tear and fatty infiltration) seen commonly in shoulders with RA[5]; (2) older than 50 years (the age limit was chosen to impose the smallest risk from radiation exposure [effective dose, 1.6 mSv] [European Union (EU) guidelines]); (3) shoulder symptoms in at least one shoulder; and (4) no previous shoulder trauma or surgery. The study had prior institutional review board approval. All patients were informed and provided signed informed consent. There were six men and 23 women with an average age of 63 years (range, 50–81 years). The mean Constant and Murley score for pain and function was 22 points (95% confidence interval [CI], 9–35 points).[164] Forty-four of the 54 shoulders were symptomatic (objective pain and loss of function) with a mean Constant and Murley score of 20. Ten shoulders were

Figure 1. The proximal migration measurement using standard AP radiographs shows moderate proximal migration of the humeral head. A = undersurface acromion, C = humeral head centre; R = humeral head radius.

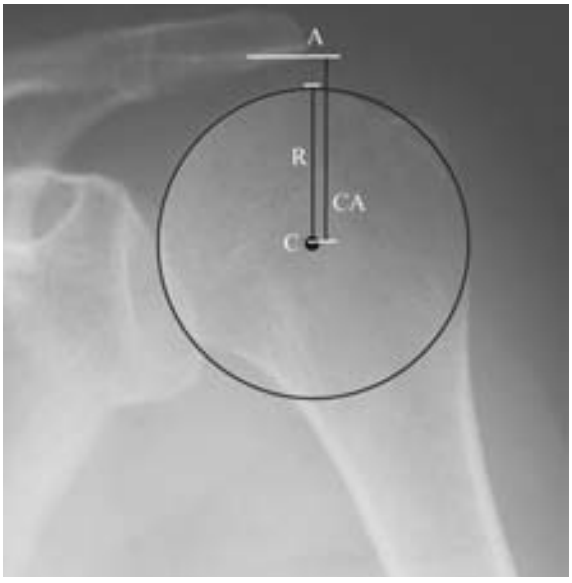
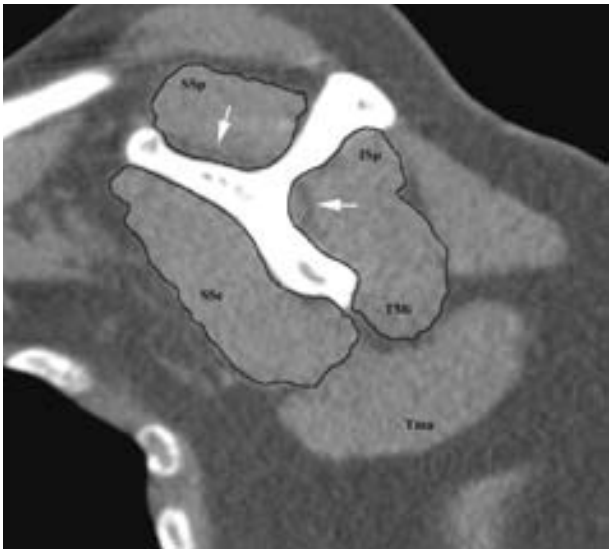


Figure 2. A parasagittal CT scan shows the regions of interest for the Supraspinatus, Infraspinatus/Teres Minor, and Subscapularis muscles (SSp, ISp/TMI, SSc). The Supraspinatus and Infraspinatus muscles show Grade 2 fatty infiltration according to Goutallier et al. White arrows; TMa = Teres Major.



asymptomatic (mean Constant and Murley score for pain and function, 28 points). The mean interval between the diagnosis of RA and the CT scan was 14 years (range, 1–40 years). Standard protocol AP radiographs were taken of all patients who were in the supine position and slightly turned to the image side (20°), with the arm in external rotation and palm facing forward.[37] The film focus distance was measured at 115 cm, and a 15° craniocaudal tilt was used to project the undersurface of the acromion perpendicular. This created a true AP projection 90° toward the shoulder (Figure 1). All radiographs were taken in a clinical setting in the presence of the principal investigator (MS) who controlled for image quality and positioning.[148] Proximal migration was measured using the upward migration index.[13] The distance between the centre of the humeral head to the undersurface of the acromion was divided by the radius of the humeral head (Figure 1). A manual circle fit was used to determine the humeral head center. An upward migration index of 1.0 indicated severe proximal migration, and an upward migration index greater than 1.26 was considered normal.[13] Previous research comparing CT images with AP radiographs suggested measuring the subacromial space on AP radiographs (controlled for positioning, scaling, and individual differences by using the upward migration index) was an accurate indicator for proximal migration.[148] All radiographs also were scored for progression of rheumatoid disease using the score described by Larsen et al.[142] Patients' shoulders were scanned with a 16-slice CT scanner (Aquilion, Toshiba, Tokyo, Japan) using a standard protocol and calibration technique. The scanning parameters were 120 kVp, 125 mAs, 250-mm field of view, and a detector pitch of 15. A reconstruction filter (FC12) and raster artefact suppression (RASP) were used to produce a 512 × 512-matrix slice thickness of 1 mm (slice overlap, 0.5 mm). Consecutive multiplanar reconstruction images were calculated with a 0.5-mm thickness in the parasagittal plane parallel to the glenohumeral joint space. The parasagittal images were evaluated from the most lateral section on which the spine of the scapula was in contact with the body of the scapula (Fig 2).[18; 143] The mean muscle density, a quantitative measure for fatty infiltration, was calculated using software developed by our division of image processing.[125] The muscles were outlined manually while carefully excluding pixels containing subcutaneous and intermuscular fat (Figure 2). The Teres Minor and Infraspinatus were analyzed together, as separating these muscles is difficult and unreliable.[19] All pixels containing bone tissue were excluded automatically from the segmentation by applying a threshold value of 200 HU. A histogram was constructed from all pixels in the outlined region of interest to calculate the mean muscle density of the rotator cuff muscles. The mean muscle density was defined as the mean CT number in one outlined rotator cuff muscle. To correct for individual muscle/fat content, the mean muscle density was divided by the patient's body mass index (BMI).[123] Because no correlation was found between BMI and proximal shoulder migration (correlation coefficient, 0.01), proximal migration was not standardized for BMI. Two blinded observers rated the rotator cuff muscles for fatty infiltration using the Goutallier score; conflicts in agreement had to be resolved.[8] This score qualitatively rates the rotator cuff muscles for fatty infiltration using a score from zero to four (0, no fat; 1, some strands of fat; 2, less fat than muscle; 3, as much fat as muscle; and 4, more fat than muscle). Mean muscle density for all rotator cuff muscles was subdivided for shoulder complaints.

All shoulders were screened for rotator cuff disease by an experienced musculoskeletal radiologist using ultrasound (Table 1). All rotator cuff muscles were screened for the presence of tendonitis, a small tear, or a massive tear using standard ultrasonic methods.[162] A general linear model of Univariate analysis was used to assess the effects of progression of RA, the presence of shoulder complaints, gender, and age on the subacromial space. Linear regression analysis and Pearson's and Spearman's correlations were used to evaluate the relation between proximal migration, the presence of a rotator cuff tear, and fatty infiltration. Analysis of variance (ANOVA) was used to assess the differences in the mean muscle density between the different patient groups. To adjust for muscle density and duration of RA and other variables, the partial correlation coefficient between the upward migration index and mean muscle density controlled for age, gender, progression of rheumatoid disease, and rotator cuff disease diagnosed by ultrasound was calculated. A Student's t test was used for detecting differences among the groups. All analyses were performed using SPSS for Windows (Version 11.05, SPSS Inc, Chicago, IL). Significance was set at $p < 0.05$.

Results

Symptomatic shoulders had smaller ($p = 0.0003$) mean muscle density when compared with asymptomatic shoulders (Table 2). The mean muscle density of the rotator cuff muscles also was smaller ($p < 0.001$) when a rotator cuff tear in the Supraspinatus and/or Infraspinatus was present (Table 2). Increase of fatty infiltration of the rotator cuff muscles was related to a decreased acromiohumeral interval as the upward migration index showed a correlation ($r=0.86$; $p < 0.0001$) with the mean muscle density of the rotator cuff muscles (Table 3). Fatty infiltration of the rotator cuff muscles accounted for 73% ($R^2=0.73$) of the variation in proximal migration of the humeral head. Rotator cuff abnormalities diagnosed by ultrasound (tendonitis, small tear, large tear) showed a weak correlation ($R^2 =0.12$; $p=0.01$) with proximal migration of the humeral head. (Tables 1 and 3). A rotator cuff tear in the Infraspinatus tendon did show a weak ($r=–0.4$; $p=0.003$) correlation with proximal migration (Table 3). The presence of a rotator cuff tear correlated ($r=0.63$) with the mean muscle density of the rotator cuff muscles (Table 4).

Table 1. Ultrasound Assessment for Rotator Cuff Abnormalities Ultrasound Assessment.

	SSp	ISp	SSc
None	18	23	35
Tendonitis	20	24	16
Small tear (<4 cm)	8	3	3
Massive tear (>4 cm)	8*	4	0

* Only one shoulder presented with retraction of more than 1 cm from the original insertion on the greater tuberosity.

SSp: Supraspinatus tendon
ISp: Infraspinatus tendon
SSc: Subscapularis tendon

There also was a probable relationship (r=–0.25) between the duration of RA and proximal migration (Table 3). The partial correlation coefficient between the upward migration index and mean muscle density controlled for age, gender, progression of rheumatoid disease, and rotator cuff disease remained (r=0.77; p<0.0001) (Table 5). A general linear model revealed no confounders for the relation between fatty infiltration and the upward migration index. The mean muscle density of the Infraspinatus/Teres Minor muscles correlated with the Upward migration Index (r=0.86) and the mean Supraspinatus density (r=0.78). The mean muscle density of the Infraspinatus/Teres Minor muscles was the best predictor (standardized coefficient beta=0.85; p<0.001; F=137.3; p<0.001) for proximal migration. Introducing both parameters, the partial correlation coefficient (r) for the Infraspinatus/Teres Minor muscles decreased from 0.85 to 0.62, and for the Supraspinatus to 0.37; beta decreased to 0.61 for the Infraspinatus/Teres Minor muscles and to 0.31 for the Supraspinatus. This showed a stronger (r=0.62) relationship between the mean muscle density of the Infraspinatus/Teres Minor muscles with proximal migration of the humeral head compared with the Supraspinatus (r=0.37). Fatty infiltration may weaken the depressing muscle force generated by the Infraspinatus/Teres Minor muscles, which allows for proximal migration of the humeral head. Suspected loss of interposition of the Supraspinatus also may play an important role, yet severe proximal migration was found only in patients with Supraspinatus tears and fatty infiltration of the Infraspinatus and Teres Minor muscles (Figure 3).

We propose three preliminary groups to discriminate between the different degrees of fatty infiltration. A large amount of fatty infiltration was indicated by an upward migration index less than 1.25, a medium amount by an upward migration index of 1.25 to 1.35, and a small amount or no fatty infiltration by an upward migration index greater than 1.35. A subdivision was made in the Goutallier score (0–1/2/3–4), resulting in three severities of fatty infiltration.[15] These three groups fit in our proposed groups (Figure 3). The mean muscle density of the rotator cuff muscles differed (p < 0.01) among the three groups (Figure 3).

Table 2. *Mean Muscle Density of the Rotator Cuff.*

	MMD SSp	MMD Isp/Tm	MMD SSc
Non-symptomatic shoulders (n=10)	39.1	47.2*	49.4
Symptomatic shoulders (n=44)	29.7	35.7*	46.8
No-tear (n=38)	37.1‡	42.7‡	49.7‡
SSp tear (n=16)	15.7‡	26.2‡	41.5‡
ISp tear (n=7)†	-10.5‡	7.4‡	31.5‡

* Significant difference in the MMD between symptomatic and non-symptomatic shoulders (p=0.003).

† All patients with an ISp tear were diagnosed also with an SSp tear.

‡ Significant difference in the MMD between the different rotator cuff tear groups (p < 0.01).

MMD: Mean muscle density, in Hounsfield Units
SSp: Supraspinatus tendon
ISp: Infraspinatus tendon
SSc: Subscapularis tendon

Table 3. Correlation Coefficients with Upward Migration Index.

R	UI	P
MMD SSp (HU)	0.78	0.0001
MMD ISp (HU)	0.85	0.0001
MMD SSc (HU)	0.53	0.0001
MMD Rotator cuff (HU)	0.86	0.0001
Rotator cuff tear, ultrasound*	-0.26	0.063
Supraspinatus tear, ultrasound*	-0.29	0.036
Infraspinatus tear, ultrasound*	-0.40	0.003
Constant score (0-35)	0.19	0.21
Larsen score* (0-5)	-0.15	0.27
Duration of RA (Yr)	-0.25	0.07
Age (Yr)	0.12	0.38

* Spearmans correlation (ordinal scale).

RA: Rheumatoid Arthritis
MMD: Mean muscle density, in Hounsfield Units (HU)
SSp: Supraspinatus tendon
ISp: Infraspinatus tendon
SSc: Subscapularis tendon

Discussion

The relationship between decreased subacromial space and rotator cuff abnormality has been assumed.[15] We sought to determine whether measuring the subacromial space on a standard AP radiograph is a reliable indicator for rotator cuff abnormality, and to present a cut-off value for proximal migration indicating a high suspicion of rotator cuff disease.

A standard protocol should be used to acquire the AP radiographs, and caution must be used in measuring upward migration when suboptimal AP radiographs are used. All radiographs should be fluoroscopically controlled for positioning to allow for easier correction and control. Also a relative measure is advocated to assess the subacromial space. We observed a greater accuracy in measuring the subacromial space using a relative measure (upward migration index) compared with the absolute acromion-humeral distance.[148] The mean absolute difference between the upward migration index measured on AP radiographs and CT images was only 0.06 (standard deviation [SD], 0.07). The mean difference for the acromion-humeral distance on CT images and AP radiographs was 2.6 mm (SD, 2.1).[148] Therefore, we think radiographs can be used reliably to screen for rotator cuff disease, but MRI, CTA, or ultrasound should be used to assess the disease in greater detail. Patient positioning (eg, upright supine) might influence the subacromial space, and therefore, should be kept constant. We found no studies comparing supine and upright positioning in radiograph measurements. To keep

this variable constant, all patients were scanned while in the supine position and all radiographs were taken with the patients in the same position. Dinnes et al reported the pooled sensitivity of ultrasound in diagnosing full and partial-thickness tears was 0.87 and 0.67, respectively. Results for the more invasive MRA were 0.95 and 0.93, respectively.[165] Therefore, the relationship between rotator cuff tears and fatty infiltration may be less precise than we would have hoped. Conversely, we think the correlation between the mean muscle density of the rotator cuff muscles and upward migration index, although not totally independent for the presence of rotator cuff tears, is strong enough to explain a major part of the proximal migration. The choice for patients with RA in assessment of rotator cuff tears, fatty infiltration, and proximal migration, allows for a wide distribution of abnormalities in a relatively small group of patients. However, the aetiology of rotator cuff tears and fatty infiltration in this patient group might differ from another patient group with rotator cuff tears or impingement.[136] Therefore generalization of our results to these patient groups might be restricted. Our results were in concordance with results in other studies of rotator cuff abnormalities and proximal migration.[15; 35; 163] Authors of these studies reported multitendon tears and/or severe fatty infiltration of the rotator cuff muscles were associated with decreased subacromial space. Proximal migration of the humeral head was compared with fatty infiltration or the presence of rotator cuff ears in just one study.[163] The results for subacromial space (8.6 versus 8.4 mm) and fatty infiltration measurement (Mean Goutallier score, 2) in

Table 4. *Pearson's Correlation Coefficients.*

R	*SSp pathology*	*ISp pathology*	*SSc pathology*
MMD SSp	0.42	0.57	0.41
MMD ISp	0.50	0.67	0.56
MMD SSc	0.40	0.45	0.43

All correlation coefficients were significant (p<0,001)

MMD: Mean muscle density, in Hounsfield Units
SSp: Supraspinatus tendon
ISp: Infraspinatus tendon
SSc: Subscapularis tendon

Table 5. *Partial correlation coefficients.*

R	*UI*	*p*
MMD SSp	0.66	0.0001
MMD ISp	0.77	0.0001
MMD SSc	0.43	0.002
MMD Rotator Cuff	0.77	0.0001

MMD: Mean muscle density, in Hounsfield Units
SSp: Supraspinatus tendon
ISp: Infraspinatus tendon
SSc: Subscapularis tendon

patients with rotator cuff tears were identical to results in our patient group.[148; 166]

Nove-Josserand et al also described a clear relationship between subacromial space measurement and fatty infiltration of the Infraspinatus, and a relation between rotator cuff tears and fatty infiltration. However, they did not report a reliable value that could be used to determine the critical degree of proximal migration indicating rotator cuff disease. Our study showed fatty infiltration of the Infraspinatus and Teres Minor muscles is the most important factor associated with proximal migration. We also presented two cut-off-values indicating healthy and abnormal rotator cuff muscles.

The proposed lower cut-off point discriminating between severe and mild fatty infiltration coincides with the mean upward migration index in healthy (unaffected) shoulders (upward migration index =1.26) described by Hirooka et al. and Lehtinen et al.[13; 140] We think a second cut-off point discriminating between healthy and mildly affected rotator cuff muscles will make it easier to screen for rotator cuff disease using the upward migration index. A third cut-off point eventually may be introduced dividing the mildly affected shoulders into two groups. When treating rotator cuff tears or placing shoulder prostheses, measuring the proximal migration of the humeral head using the upward migration index provides a reliable screening method indicating fatty infiltration of the rotator cuff. It provides valuable information for surgical planning and functional prognosis. Additional research regarding clinical implications of fatty infiltration is needed to evaluate and improve its diagnostic value.

Figure 3. *A scatter plot shows the upward migration index as a function of the mean muscle density of the rotator cuff muscles. The linear regression line (mean muscle density = 1.08 + 0.14 * upward migration index; p < 0.0001) indicates a very strong relation between both measures.*