Contrast-enhanced MRI of the subdeltoid, subacromial bursa in painful and painless rotator cuff tears

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Objective: Although shoulder pain is often associated with rotator cuff tears, many tears are asymptomatic and are not the cause of the patient's pain. This may explain the persistence of symptoms in some patients despite technically successful rotator cuff repair. It has been proposed that rotator cuff tears cause pain through subdeltoid/subacromial bursal inflammation. The aim of this study was to determine whether bursal inflammation seen on MRI is associated with pain in patients with rotator cuff tears of the shoulder.

Methods: The shoulders of 255 patients were screened with ultrasound. 33 full-thickness rotator cuff tears (18 with shoulder pain and 15 without pain) were identified and subsequently studied using contrast-enhanced MRI of the shoulder. Enhancement of the subacromial bursa was scored independently by two musculoskeletal radiologists. Logistic regression was used to determine whether bursal enhancement was independently associated with pain.

Results: There was a significant association between pain and age, with greater likelihood of pain in younger patients. Bursal enhancement was common in both painful and painless tears. No statistically significant link between pain and bursal enhancement was seen, even after accounting for age.

Conclusion: Although enhancement of the subdeltoid/subacromial bursa was common, no evidence was found to support the hypothesis that bursal enhancement is associated with pain in rotator cuff tears. It is therefore unlikely to determine reliably which patients would benefit from rotator cuff repair.

Advances in knowledge: Bursal enhancement and thickening does not reliably correlate with symptoms or presence of rotator cuff tear.

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Rotator cuff tears are a common cause of pain in the shoulder. Surgical repair is an effective treatment, but a significant proportion of patients (5–12.5%) fail to achieve a satisfactory outcome [1–4]. Long-term outcome of surgery correlates poorly with the integrity of the cuff repair [5–7] and persistence of pain is a major factor [1]. In some cases, this may be because the shoulder pain is not due to rotator cuff damage at all [8]. Other painful shoulder pathologies are common, particularly in the elderly, including glenohumeral and acromioclavicular arthritis [9], and bone marrow oedema [10]. Asymptomatic rotator cuff tears are common, with increasing incidence with age and a reported prevalence of up to 80% in subjects aged over 80 years [11]. A significant proportion of these are full-thickness tears with one study reporting full-thickness tears in 28% of people over the age of 60 [12]. Rotator cuff tears may remain asymptomatic despite their large size [13] and, although the size of tears often

increases, symptoms may develop or resolve with conservative treatment [14–16]. As yet there is no clear consensus regarding the indications for rotator cuff surgery [17, 18]. A technique to determine whether a known rotator cuff tear is responsible for an individual patient's pain would therefore be of great clinical value in developing patient management plans. While MRI has been shown to be accurate for detecting rotator cuff tears [19, 20], there is no convincing evidence to date that it can be used to determine whether a full-thickness tear is symptomatic [12, 21].

The mechanism by which rotator cuff tears cause pain is poorly understood. Tears are associated with histological inflammation of the subdeltoid/subacromial bursa and this has recently been proposed as a cause of pain [22]. Synovial inflammation in the bursa in symptomatic rotator cuff tears could potentially be detected by the associated enhancement in the inflamed bursa seen on MRI after the administration of intravenous contrast agent, in the same way that synovial volume in joints in inflammatory arthritis has been shown to correlate with histological measures of inflammation [23]. The aim of this study was to use contrast-enhanced MRI to assess subacromial bursitis in patients with painful and pain-

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less rotator cuff tears in order to test the hypothesis that synovial enhancement at the subacromial bursa is greater in patients with shoulder pain.

Methods and materials

Patients

A group of patients with rotator cuff tears and shoulder pain was recruited from consecutive primary care clinical referrals to the shoulder ultrasound service for shoulder pain with sonographic evidence of a full-thickness rotator cuff tear.

A group of patients with a rotator cuff tear without shoulder symptoms was recruited from consecutive referrals for ultrasound of other regions. Ultrasound of the shoulder was performed and those patients with an incidental full-thickness rotator cuff tear were included in the study. Participants were questioned about the presence of any shoulder symptoms and excluded if they reported any symptoms within the preceding year, there was a history of trauma to the shoulder or the patient had a clinical diagnosis of arthritis involving the shoulder or any other joint.

The study was approved by the local research ethics committee and informed consent was obtained from all participants.

Patient symptoms

Participants completed a shoulder rating questionnaire to assess shoulder pain and its limitation of activity, recreation and work [24]. The global domain score is measured on a 10 cm visual analogue score line ranging from 0 (very poorly) to 10 (very well). The remaining domain scores are calculated from the responses to various questions measured on rating scales; each has a minimum of two (indicating the most severe symptoms) and a maximum of 10 (indicating no symptoms).

Ultrasound

Ultrasound was performed by an experienced consultant musculoskeletal radiologist using an Antares ultrasound machine with a 13.5 MHz linear array transducer (Siemens Healthcare, Erlangen, Germany). The presence or absence of a full-thickness rotator cuff tear was determined using the local standardised ultrasound scanning protocol [25].

MRI

MRI images of the shoulder were acquired using a 1.5T Gyroscan AXS-NT Scanner (Philips, Best, Netherlands) and a dedicated shoulder coil with the arm by the side in the neutral position. The following images were acquired:

- proton density-weighted coronal-oblique: repetition time (TR), 2628 ms; echo time (TE), 15 ms; slice thickness, 3 mm; field of view, 16 cm; 256 × 177 matrix

- T_2 weighted coronal-oblique fat-suppressed: TR, 5332 ms; TE, 100 ms; slice thickness, 3 mm; field of view, 16 × 13 cm; 256 × 201 matrix)
- STIR sagittal-oblique: TR, 1200 ms; TE, 15 ms; slice thickness, 4 mm; field of view, 16 × 13 cm; 256 × 204 matrix.

T_1 weighted images were acquired before and after the administration of 0.1 mmol kg⁻¹ gadopentetate dimeglumine (Magnevist, Bayer Schering, Leverkusen, Germany) in the coronal-oblique (TR, 500 ms; TE, 15 ms; slice thickness, 3 mm; field of view, 16 × 13 cm; 256 × 154 matrix) and sagittal (TR, 375 ms; TE, 14 ms, slice thickness, 3 mm; field of view, 16 × 13 cm; 256 × 154 matrix) planes. Contrast-enhanced images were acquired with fat suppression.

MRI scoring

MRI images were assessed independently by two experienced consultant musculoskeletal radiologists blinded to symptoms. Enhancement of the subacromial bursa was assessed using T_1 weighted fat-suppressed sagittal-oblique and coronal-oblique contrast-enhanced images. Images were scored on a scale of 0–2 depending on the maximum thickness of enhancing tissue: 0, no abnormal enhancement; 1, up to 3 mm thickness of enhancing tissue; 2, 3 mm or more enhancing tissue (Figures 1 and 2).

Statistics

To compare agreement between the two observers, the kappa statistic was calculated for the subacromial bursal enhancement scores, in addition to prevalence-adjusted, bias-adjusted kappa (PABAK) [26] and the proportion of scores over which the raters were in exact agreement (PEA). Category-specific proportions of agreement, representing the probability that the second scorer would place a subject in that specific category given that the first scorer placed them in that category, were also calculated.

To determine whether subacromial bursal enhancement was linked to shoulder pain, exact binary logistic regression was performed with age, sex and bursal enhancement as independent variables; adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each. Analyses were conducted in SPSS® v. 18.0.3 (SPSS Inc., Chicago, IL) and LogXact® v. 8.0 (Cytel Inc., Cambridge, MA).

Results

18 rotator cuff tears were found out of a total of 53 patients undergoing ultrasonography for shoulder pain. 31 rotator cuff tears were found out of a total of 202 patients undergoing ultrasonography of other regions; 11 met exclusion criteria and 5 patients were unable to tolerate MRI, leaving 15 patients with painless tears.

Symptomatic patients were younger on average (mean symptomatic=55.4, 95% CI=52.2–58.7; asymptomatic=65.2,

(a)

(b)

Figure 1. Grade 2 subacromial bursitis. There is enhancing tissue >3 mm in thickness in the subacromial bursa.

95% CI=61.1–69.3) and a much larger proportion were female (proportion symptomatic=72% (13/18), 95% CI=49–88%; asymptomatic=13% (2/15), 95% CI=3–38%).

MRI confirmed the presence of a full-thickness tear of the rotator cuff in all patients diagnosed on ultrasound (e.g. Figure 3). The mean size of the rotator cuff tear was 2.4×2.3 cm in the asymptomatic group and 2.1×2.0 cm in the symptomatic group.

The results of the shoulder symptoms questionnaire are shown in Table 1. Two subjects did not complete the questionnaire. One subject in the asymptomatic group subsequently reported mild symptoms on the

questionnaire. As expected, scores were considerably lower in the subjects with pain.

The kappa statistic for interobserver agreement of the subdeltoid/subacromial bursal enhancement score was 0.61 (95% CI=0.22–1.00). The prevalence index (the imbalance in the distribution of scores) was 72.7%; when this was accounted for the adjusted kappa was higher (PABAK=0.82). The raters exactly agreed over the majority of scores (PEA=90.9%); however, the agreement was poorer for Grade 2 (66.7%) than for Grade 1 (94.7%).

Subdeltoid/subacromial enhancement ($\geq$ Grade 1) was seen in all patients in both the symptomatic and asymptomatic group. Grade 2 enhancement was seen in most shoulders (29/33; 88% overall), including 12/15 (80%) of asymptomatic and 17/18 (94%) of symptomatic patients.

Exact binary logistic regression indicated that the odds of a tear being symptomatic reduced with age (OR=0.84, 95% CI=0.69–0.98, $p=0.021$) and may be increased in females (OR=8.91, 95% CI=0.83–460.48, $p=0.082$), but having controlled for these factors there was no clear association between pain and subacromial enhancement (OR=20.44, 95% CI=0.03–22347.73, $p=1.00$).

Discussion

The aim of the current study was to determine whether shoulder pain was associated with contrast enhancement at the subacromial bursa in patients with rotator cuff tears. There was no significant evidence for a link between pain and enhancement, with only slightly greater enhancement in the group with shoulder pain. No significant association was found between pain and enhancement despite taking into account the age and sex differences between the symptomatic and asymptomatic patient groups, although increased age was associated

Figure 2. Grade 1 subacromial bursitis. There is enhancing tissue <3 mm in thickness in the subacromial bursa.

Table 1. Shoulder rating questionnaire results

Factor	Asymptomatic	Symptomatic
Global health	9.7 (8.1–10.0), <i>n</i> =14	2.8 (2.0–4.9), <i>n</i> =16
Pain	10.0 (10.0–10.0), <i>n</i> =14	5.0 (3.9–5.5), <i>n</i> =17
Activity	All scored 10, <i>n</i> =14	6.0 (5.2–6.5), <i>n</i> =17
Recreation	All scored 10, <i>n</i> =14	5.3 (4.0–6.0), <i>n</i> =17
Work	All scored 10, <i>n</i> =13	7.5 (3.5–8.9), <i>n</i> =10

Data show median (interquartile range in parentheses). Greater symptoms resulted in lower scores (maximum 10 for each domain).

with painless rotator cuff tears. Were more subjects to be included in a future study, a statistically significant association with subacromial enhancement might emerge, but assuming the same large proportion of patients had Grade 2 subacromial enhancement its predictive utility would nevertheless be limited. The high level of enhancement in asymptomatic patients (80% showed Grade 2 enhancement) means subdeltoid/subacromial enhancement is unlikely to be useful for discriminating between painful and painless rotator cuff tears.

These results have implications for understanding the mechanisms for pain in rotator cuff tears. Since bursitis was common in the asymptomatic group, it seems unlikely that the presence of subacromial bursitis (as determined by MRI) is the sole determinant of pain in patients with rotator cuff pathology. This is consistent with a previous study that looked at the volume of fluid in the subdeltoid/subacromial bursa using indirect magnetic resonance arthrography [27], finding no relationship to shoulder symptoms. Other studies have looked at other factors that may be related to rotator cuff pain and have shown mixed results for tear size,

with a link between symptoms and tear size demonstrated in larger studies compensating for age [28, 29].

Our study showed an incidence of full-thickness rotator cuff tears on shoulder ultrasound of 15% without shoulder symptoms referred for ultrasound for other reasons. The mean age of these patients was 66 years. This is consistent with a large previously reported study of full-thickness tears in asymptomatic volunteers over 50 years of age, which showed an overall incidence of 8%, with a strong dependence on age [30].

Logistic regression was used in the current study to allow the relationship between bursal enhancement and pain to be studied independently of patient age. In this study population, the age of patients in the group with shoulder pain was lower than that of patients without pain. A similar age difference was seen in a recent publication comparing symptomatic and asymptomatic tears [29], although this has not been present in all studies [31], possibly reflecting differences in underlying study populations. In particular, it seems likely that younger patients with symptoms may be referred more commonly for ultrasound assessment at our institution.

Interobserver reproducibility for subacromial bursal enhancement assessed using the three-point scoring system presented was fair to good ($\kappa=0.61$) [32]. The high levels of bursitis identified in both symptomatic and asymptomatic patients (>85% patients scoring the maximum in both groups) might suggest a grading system with more points (subdividing Group 2) could be used, but the authors felt this would reduce interobserver agreement. Direct volume measurement of enhancing bursitis might be an alternative, as for joint synovitis [33], and has the advantage of providing a continuous measure with the potential to discriminate better between groups; however, the high surface area of the

(a)

(b)

Figure 3. Example of an asymptomatic patient with a large rotator cuff tear and marked changes, including reduction of the distance between the acromion and the humeral head, supraspinatus atrophy, subacromial, glenohumeral and acromioclavicular enhancement, and subchondral oedema.

subdeltoid/subacromial bursa would be likely to impact on the reproducibility of such measurements.

A limitation of this study is the small size of the groups, and particularly the asymptomatic group, which consisted of only 15 subjects, despite screening over 200 participants. This study would allow the formal powering of a larger study to detect statistically significant differences between symptomatic and asymptomatic groups. Such a study would also benefit from age-matching of the symptomatic and asymptomatic groups. Nevertheless, given the high levels of synovitis demonstrated in patients without shoulder pain in the current study and the inability to detect a significant difference between groups of 15–18 subjects, it is clear that the presence of enhancing synovitis is extremely unlikely to be clinically useful for determining whether pain in a particular patient is the result of an underlying rotator cuff tear. Another limitation of the study to be considered is the underlying assumption that bursal inflammation correlates with MRI enhancement. Although the link between MRI enhancement and histological markers of inflammation has been demonstrated in the knee in rheumatoid arthritis, this has not been proven for subacromial bursitis [23], and dynamic contrast-enhanced MRI may be a better measurement of inflammatory activity [34–37].

In conclusion, this study showed enhancement in the subdeltoid/subacromial bursa is common in the presence of a rotator cuff tear both in patients with shoulder pain and in patients without pain. No evidence was found to support the hypothesis that pain is closely related to synovial enhancement due to subacromial bursal inflammation. Bursal enhancement is unlikely to be helpful in determining whether shoulder pain is arising from a rotator cuff tear.

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