The accuracy of plain radiographs in diagnosing degenerate rotator cuff disease

Kuen Chin, Alex Chowdhury, Dimitra Leivadiotou,
Helen Marmery and Philip Michael Ahrens

Abstract

Background: A number of radiographic signs have been previously demonstrated to be associated with degenerative rotator cuff tears. An ability to predict the presence of a tear by radiography would permit the early commencement of appropriate treatment and the avoidance of unnecessary invasive investigations. The aim of the present study was to determine the accuracy of using radiographic signs to predict the presence of a cuff tear on arthroscopy.

Methods: Fifty consecutive patients who had undergone shoulder arthroscopy and had pre-operative plain radiographs were included. Pre-operative radiographs were reviewed by a consultant shoulder surgeon, a consultant radiologist and a senior clinical fellow for the following signs: acromial spur; subjective reduction of subacromial space; sourcil sign; acromial acetabularization; os acromiale; greater tuberosity cortical irregularity; greater tuberosity sclerosis; humeral head rounding; cyst; and reduction in acromiohumeral head distance.

Results: The presence of tuberosity sclerosis ($p < 0.0001$), tuberosity irregularities ($p < 0.0001$), tuberosity cyst ($p = 0.004$) and sourcil sign ($p = 0.019$) was associated with the presence of a rotator cuff tear. The combined sensitivity of prediction of tear by the observers following radiographic review was 91.7%, with a combined negative predictive value of 80%.

Conclusions: The assessment of radiographs by senior clinicians is a useful tool for confirming the absence of a rotator cuff tear.

Keywords

arthroscopy, radiography, rotator cuff, X-rays

Date received: 21st February 2017; revised: 25th July 2017; accepted: 17th October 2017

Introduction

Rotator cuff tears are amongst the most common of shoulder pathologies presenting to the orthopaedic clinic. They have an estimated prevalence of 22%, increasing with age.¹ The primary imaging modalities for the diagnosis of cuff tears are ultrasonography (US) and magnetic resonance imaging (MRI). Recent meta-analyses have demonstrated these modalities to exhibit high sensitivities and specificities, particularly for full-thickness tears.^{2,3} US is relatively inexpensive and quick to perform, although it is very operator dependent. MRI also provides a detailed evaluation of surrounding structures, although it is costly and less readily accessible.

Plain radiography is typically the initial imaging modality for patients presenting to a shoulder clinic.

An ability to predict rotator cuff disease on initial radiography may enable the early commencement of appropriate treatment and confer greater patient satisfaction, as well as minimize the need for costly secondary imaging. A number of radiographic signs have been suggested to be associated with postero-superior cuff tears (supraspinatus and infraspinatus), including an acromial spur, a reduced subacromial space, sourcil sign, acromial acetabularization, greater tuberosity irregularity, humeral head sclerosis, humeral head

Royal Free London NHS Foundation Trust, London, UK

Corresponding author:

Kuen Chin, Ponders Street, Royal Free London NHS Foundation Trust,
London NW3 2QG, UK.
Email: chinkuenfoo@yahoo.com

rounding, soft tissue calcification, an os acromiale and a reduced acromio–humeral head distance.^{4–16} Cortical irregularity of the greater tuberosity has been demonstrated previously, in both radiographic and US studies, to be an indicator of cuff tear (high specificity, modest sensitivity).^{14,17} Evidence of a positive association of greater tuberosity sclerosis with cuff tear has proved more inconsistent. In a study of arthroscopically proven cuff tears, Pearsall et al.¹⁰ demonstrated a significant association. This is in contrast to an earlier study by Huang et al.⁹ However, this earlier study had used MRI to determine the presence of a cuff tear, which is less sensitive than arthroscopy.

The aim of the present study was to determine the accuracy of plain radiographic findings with respect to predicting the presence of a rotator cuff tear, in isolation or in combination, by comparison with the gold standard of arthroscopy. Thus, the null hypothesis was that there is no relationship between the presence of radiographic signs and a rotator cuff tear.

Materials and methods

Cases were identified retrospectively at the Royal Free Hospital, London. The study was approved by the trust research governance board. Fifty consecutive patients, who had reached skeletal maturity and had undergone shoulder arthroscopy between January 2011 and December 2013, had been randomly selected to avoid selection bias. Inclusion criteria included the presence of pre-operative shoulder radiographs and the use of shoulder arthroscopy. Exclusion criteria included patients with first-time shoulder dislocation or acute rotator cuff tear because radiographs would be expected to be normal in these cases. Eligible patients were then allocated a specific patient research assignment number to ensure observer blindness. Of the 50 patients selected for the present study, 42 patients had presumptive diagnosis of rotator cuff disease, four had presumptive diagnosis of adhesive capsulitis and four had recurrent instability.

Standard true anteroposterior and lateral views of the shoulder were reviewed by three assessors: a musculoskeletal radiologist, a senior consultant shoulder surgeon and a senior clinical fellow. The assessments were then repeated after a 3-week interval. The images were reviewed on a digital picture archiving and communication system (PACS). Eleven parameters were studied, which can be largely divided into acromion related pathologies (acromial spur, subjective reduction of subacromial space, sourcil sign, acromial acetabularization, os acromiale) and humeral head pathologies (greater tuberosity cortical irregularity, greater tuberosity sclerosis, humeral head rounding, the presence of a cyst, reduction in acromio–humeral

head distance) (Figs 1 and 2). The study parameters were scored using dichotomous outcome (presence or absence). The acromio–humeral distance was also measured and classified into dichotomous outcome (normal or reduced) using 6-mm as a cut-off in accordance with Goutallier et al.¹⁶ Following radiographic assessment, the assessors also made a pragmatic diagnosis of the

Figure 1. An anteroposterior radiograph of a right shoulder demonstrating acromial sclerosis (black arrow).

Figure 2. An axial radiograph of a right shoulder demonstrating greater tuberosity cortical irregularity (black arrow).

presence or absence of a cuff tear. Operating notes and arthroscopic photographs were reviewed by a separate senior clinical fellow to determine the presence of a cuff tear. For the present study, we defined a positive postero–superior cuff tear as a full-thickness tear or a > 50% thickness tear because these represent significant cuff pathology.¹⁸

Statistical analysis

The data were analyzed using the SPSS, version 22 (IBM Corp., Armonk, NY, USA). Intra- and inter-observer variability was expressed using Cohen's kappa coefficient. The predictions from all three observers were reported individually and the average prediction calculated. The sensitivity, specificity and prediction values for the average prediction were determined. Chi-squared tests were carried out to investigate the correlation between each parameter with the status of the cuff. Because these parameters often co-exist in one radiograph, relationships may not be evident in one-dimensional analysis. Hence, we carried out dimension reduction analysis to examine the distribution and grouping of these 11 covariates with cuff tear. The variables that were closely related were then examined further with categorical regression analysis and optimal scaling.

RESULTS

Baseline characteristics

The mean (SD) age of the study cohort was 51.8 (16.6) years (range 17 years to 81 years). Of the 50 patients, 24 (48%) had a full-thickness tear or a tear greater than 50%; two had a partial tear of < 50% (4%) and 24 had no tear (48%). The mean (SD) age was 57.9 (14.5) years (range 33 years to 81 years) for those patients with a full-thickness tear. The mean age of patients without a tear was 46.2 years (range 17 years to 71 years).

Radiographic parameters

One hundred percent (100%; 24/24) of patients with a > 50% postero–superior cuff tear had three or more radiographic signs compared to 23% (6/26) of those with a partial or no tear. Of the six patients who had more than three radiological signs, one had adhesive capsulitis, whereas the other five had combination of at least two of the following pathologies: partial articular side cuff tear of less than 50%, long head of biceps pathology or a subscapularis tear.

The chi-squared test demonstrated tuberosity sclerosis, tuberosity irregularities, tuberosity cyst and

Table 1. Correlation of cuff tear with radiographic parameters.

Cross-tabulation pairing	Pearson's chi-squared significance
Cuff tear–spur	$p = 0.616$
Cuff tear–subacromial space reduction	$p = 0.048$
Cuff tear–Sourcil sign	$p = 0.019$
Cuff tear–acetabularization of acromion	Not computed because no radiograph had this sign
Cuff tear–tuberosity sclerosis	$p < 0.0001$
Cuff tear–tuberosity irregularities	$p < 0.0001$
Cuff tear–tuberosity cyst	$p = 0.004$
Cuff tear–rounding of humeral head	$p = 0.048$
Cuff tear–calcification	$p = 0.917$
Cuff tear–os-acromiale	$p = 0.332$
Tear versus reduced acromio–humeral distance	$p = 0.026$

sourcil sign to be significantly associated with the presence of a rotator cuff tear (Table 1).

We examined the relationship of the covariates with principal component analysis and confirmed that these four factors were commonly associated with cuff tear. The Kaiser–Meyer–Olkin measure of sample adequacy was 0.72 and Bartlett's test of sphericity was significant ($p < 0.0001$). The rotated component matrix showed that humeral side radiological signs commonly co-exist with cuff pathology. The principal components that are grouped together with cuff pathology were tuberosity sclerosis, tuberosity irregularities and tuberosity cyst. The only acromion side radiological sign that was weakly related to cuff tear was the sourcil's sign. This is illustrated in Fig. 3, which shows the grouping of cuff tear with tuberosity sclerosis, tuberosity irregularities, tuberosity cyst and sourcil sign.

Using the covariates identified from the principal component analysis, we carried out regression analysis to confirm the predictability of these covariates. Categorical regression analysis showed an r^2 value of 0.44. The model also confirmed that tuberosity irregularity has the biggest effect on predicting cuff tear (standardized co-efficient, $\beta = 0.41$), followed by tuberosity

Figure 3. Graph showing grouping of cuff tear with tuberosity sclerosis, tuberosity irregularities, tuberosity cyst and sourcil sign (black dots).

Key: surgtear = tear confirmed on arthroscopy; cystaverage = presence of cyst; scleraverage = presence of sclerosis; irregaverage = irregularities on greater tuberosities; sourcilaverage = sourcil sign.

Table 2. Accuracy and reliability of prediction of cuff tear.

Assessor	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Intra-observer reliability (Cohen's kappa; SE)	Inter-observer reliability (Fleiss' kappa)
Fellow	62.5%	50%	53.6%	59%		0.566 (all 3); 0.75 (radiologist versus consultant surgeon)
Musculoskeletal radiologist	87.1%	48.1%	61.6%	83.5%	0.716 (0.1)	
Shoulder surgeon	81.3%	40.4%	57.4%	70%	0.714 (0.1)	
Consensus prediction	91.7%	30.8%	55%	80%		

sclerosis (0.145) and tuberosity cyst (0.151) and, to a lesser extent, sourcil sign (0.043).

Reliability of prediction

The sensitivity, specificity, positive predictive value and negative predictive value of the prediction by the fellow were 62.5%, 50%, 53.6% and 59%, respectively (Table 2). The sensitivity, specificity positive predictive value and negative predictive value of the prediction by the MSK radiologist were 87.1%, 48.1%, 61.6% and 83.5%, respectively. The sensitivity, specificity positive predictive value and negative predictive value of the prediction by the shoulder surgeon were 81.3%, 40.4%, 57.4% and 70%, respectively.

The prediction was repeated twice by each assessor (except the fellow). We derived an average prediction by using the consensus of prediction for each patient from all three assessors. The average prediction was more reliable. The sensitivity, specificity, positive predictive value and negative predictive value were 91.7%, 30.8%, 55% and 80%, respectively. Repeat analysis using the cohort with higher prevalence (age > 30 years) did not change the reliability. The consensus prediction had a high sensitivity and high negative predictive value (i.e. good at ruling out cuff tear).

The intra-observer reliability was 0.7 (Cohen's kappa; standardized error 0.1) and the inter-observer error between all three assessors was 0.566 (Fleiss' kappa). The inter-observer reliability between

the MSK radiologist and senior consultant was 0.75 (Fleiss' kappa).

Discussion

The present study has demonstrated plain radiography to be useful in detecting and ruling out a rotator cuff tear, particularly when reviewed by a senior orthopaedic surgeon or musculoskeletal radiologist (combined sensitivity of 91.7% and negative predictive value of 80%). The specificities and positive predictive value are less satisfactory. This contrasts with the relatively high sensitivities exhibited by both US and MRI.^{2,3} However the reliability of the prediction would undoubtedly have been enhanced when taken into context with history and clinical examination.

The results of the present study also showed that patients with more than three abnormal radiological signs are likely to have a cuff tear. The abnormal radiological signs on the humeral side are more predictive of cuff tear. These include sclerosis of the tuberosity, irregularities of the tuberosity and the presence of cystic changes on the tuberosity. The presence of sourcil sign is a weak predictor, although this may be the result of a type II error because sourcil sign is rare in our cohort of mainly middle age patients (mean age 51.8 years). The findings from our study will help the clinicians to target further investigation and treatment to the 'at risk' group and save cost for not investigating the 'normal' group. In addition, the ability to predict the diagnosis and response in the clinic will also improve patient satisfaction, particularly in clinics that do not provide a one-stop scanning service.

Several plain radiographic findings have been previously suggested to reflect the presence of a rotator cuff tear,⁴⁻¹⁶ although their utility in the diagnosis of tears remains controversial. In 2000, Bonsell et al.¹⁹ observed a number of radiographic changes (including acromial cysts, acromial sclerosis and acromioclavicular joint narrowing) that were associated with increasing age in a study of asymptomatic individuals. However, the subjects in their study¹⁹ were not otherwise evaluated for rotator cuff pathology (tears are asymptomatic in approximately two-thirds of individuals).¹

Several studies have demonstrated a reduced acromio-humeral head distance to be associated with a rotator cuff tear.^{13,16} Indeed, Saupe et al.¹³ demonstrated a significant negative correlation between acromio-humeral head distance and the size of the tear. This sign was not found to be significant in the present study. This may be because it is a relatively late sign of rotator cuff disease and often reflects cuff decompensation with progression to cuff tear arthropathy. These patients may be less likely to undergo arthroscopic treatment. It has been shown that a short acromio-humeral distance

represents a reduced likelihood of reparative success.²⁰ Hence, it may not be useful in the management of a younger cohort with a reparable cuff tear.

The strengths of the present study include the blinded and repeated radiographic analysis that was performed. The study included 11 previously described radiographic findings, giving a more comprehensive assessment than previous studies. Thus, it could identify a combination that confers an increased risk of cuff tear. It also used arthroscopic determination of rotator cuff status, which is the gold standard for diagnosis.

The weaknesses of the present study include a relatively small sample size, with all patients requiring arthroscopy, which may cause a bias towards symptomatic disease and the possible presence of other shoulder pathologies, as well as patient suitability for arthroscopic intervention.

Conclusions

In conclusion, the assessment of plain radiography of the shoulder by senior practitioners is useful for confirming the absence of a rotator cuff tear. This supports the modality's ongoing status as the first-line investigation for shoulder pathology. When combined with a careful history and clinical examination, it will help guide the use of further radiological investigations, obviating unnecessary waiting times and tests for many without cuff tears.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical Review and Patient Consent

Not required for this article.

References

1. Minagawa H, Yamamoto N, Abe H, et al. Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: from mass-screening in one village. *J Orthop* 2013; 10: 8–12.
2. Smith TO, Back T, Toms AP, et al. Diagnostic accuracy of ultrasound for rotator cuff tears in adults: a systematic review and meta-analysis. *Clin Radiol* 2011; 66: 1036–1048.
3. Smith TO, Daniell H, Geere JA, et al. The diagnostic accuracy of MRI for the detection of partial-and full-thickness rotator cuff tears in adults. *Magn Reson Imaging* 2012; 30: 336–346.

4. Hamid N, Omid R, Yamaguchi K, et al. Relationship of radiographic acromial characteristics and rotator cuff disease: a prospective investigation of clinical, radiographic, and sonographic findings. *J Shoulder Elbow Surg* 2012; 21: 1289–1298.
5. Oh JH, Kim JY, Lee HK, et al. Classification and clinical significance of acromial spur in rotator cuff tear: heel-type spur and rotator cuff tear. *Clin Orthop* 2010; 468: 1542–1550.
6. Loew M, Magosch P, Lichtenberg S, et al. How to discriminate between acute traumatic and chronic degenerative rotator cuff lesions: an analysis of specific criteria on radiography and magnetic resonance imaging. *J Shoulder Elbow Surg* 2015; 24: 1685–1693.
7. Smith C, Dattani R, Deans V, et al. The sourcil sign: a useful finding on plain X-ray? *Shoulder Elbow* 2010; 2: 9–12.
8. Hamada K, Fukuda H, Mikasa M, et al. Roentgenographic findings in massive rotator cuff tears. A long-term observation. *Clin Orthop* 1990; 254: 92–96.
9. Huang LF, Rubin DA and Britton CA. Greater tuberosity changes as revealed by radiography: lack of clinical usefulness in patients with rotator cuff disease. *AJR Am J Roentgenol* 1999; 172: 1381–1388.
10. Pearsall AW, Bonsell S, Heitman RJ, et al. Radiographic findings associated with symptomatic rotator cuff tears. *J Shoulder Elbow Surg* 2003; 12: 122–127.
11. Suluova F, Kanatli U, Ozturk BY, et al. Humeral head cysts: association with rotator cuff tears and age. *Eur J Orthop Surg Traumatol* 2014; 24: 733–9.
12. Hershkovich O. Role of radiographs in shoulder pathology: a clinical review. *Reports in Medical Imaging* 2014; 7: 75–80.
13. Saupe N, Pfirrmann CW, Schmid MR, et al. Association between rotator cuff abnormalities and reduced acromiohumeral distance. *AJR Am J Roentgenol* 2006; 187: 376–382.
14. Pandey S, Brihan JB, Huang TL, et al. Does shoulder radiography predict rotator cuff abnormality? Examination of greater tuberosity cortical irregularity as an indicator for supraspinatus pathology. Scientific Assembly and Annual Meeting, Chicago, IL, USA, 26 November to 2 December 2011. Radiological Society of North America. Poster presentation in 2011 RSNA conference. RSNA location: Oak Brook, Illinois, USA.
15. Van der Reijden JJ, van den Bekerom M, Somford M, et al. Radiographic signs predicting rotator cuff tears. European Society of Musculoskeletal Radiology, York, UK, 18 to 20 June 2011. European Society of Musculoskeletal Radiology. Poster presentation in 2015 ESSR conference. ESSR location: Vienna, Austria.
16. Goutallier D, Le Guilloux P, Postel JM, et al. Acromiohumeral distance less than six millimeter: its meaning in full-thickness rotator cuff tear. *Orthop Traumatol Surg Res* 2011; 97: 246–251.
17. Jacobson JA, Lancaster S, Prasad A, et al. Full-thickness and partial-thickness supraspinatus tendon tears: value of US signs in diagnosis 1. *Radiology* 2004; 230: 234–242.
18. Weber SC. Arthroscopic debridement and acromioplasty versus mini-open repair in the treatment of significant partial-thickness rotator cuff tears. *Arthroscopy* 1999; 15: 126–131.
19. Bonsell S, Pearsall AW, Heitman RJ, et al. The relationship of age, gender, and degenerative changes observed on radiographs of the shoulder in asymptomatic individuals. *Bone Joint J* 2000; 82: 1135–1139.
20. Chung SW, Oh JH, Gong HS, et al. Factors affecting rotator cuff healing after arthroscopic repair osteoporosis as one of the independent risk factors. *Am J Sports Med* 2011; 39: 2099–2107.