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SCIENTIFIC ARTICLE

Magnetic resonance imaging and magnetic resonance arthrography of the shoulder: dependence on the level of training of the performing radiologist for diagnostic accuracy

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Abstract
Purpose Discrepancies were identified between magnetic resonance (MR) imaging and clinical findings in patients who had MR imaging examinations evaluated by community-based general radiologists. The purpose of this study was to evaluate the diagnostic performance of MR imaging examinations of the shoulder with regard to the training level of the performing radiologist.

Methods A review of patient charts identified 238 patients (male/female, 175/63; mean age, 40.4 years) in whom 250 arthroscopies were performed and who underwent MR imaging or direct MR arthrography in either a community-based or hospital-based institution prior to surgery. All MR imaging and surgical reports were reviewed and the diagnostic performance for the detection of labral, rotator cuff, biceps, and Hill–Sachs lesions was determined. Kappa and Student's *t* test analyses were performed in a subset of cases in which initial community-based MR images were re-evaluated by hospital-based musculoskeletal radiologists, to determine the interobserver agreement and any differences in image interpretation.

Results The diagnostic performance of community-based general radiologists was lower than that of hospital-based sub-specialized musculoskeletal radiologists. A sub-analysis of re-evaluated cases showed that musculoskeletal radiologists performed better. κ values were 0.208, 0.396, 0.376, and 0.788 for labral, rotator cuff, biceps, and Hill–Sachs lesions (*t* test statistics: p=<0.001, 0.004, 0.019, and 0.235).

Conclusions Our results indicate that the diagnostic performance of MR imaging and MR arthrography of the shoulder depends on the training level of the performing radiologist, with sub-specialized musculoskeletal radiologists having a better diagnostic performance than general radiologists.

Keywords Magnetic resonance imaging · Magnetic resonance arthrography · Arthroscopy · Shoulder · Experience

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Introduction

Magnetic resonance (MR) imaging has proved to be useful in the assessment of acute or chronic shoulder disorders [1].

Reported sensitivities and specificities, dependent on the specific structure evaluated, have been reported to be between approximately 65–95% and 78–100% [2–7]. The diagnostic performance of MR imaging of the shoulder for certain disorders can be increased by the administration of a gadolinium-based contrast agent, which is typically injected directly into the joint space under fluoroscopic guidance (referred to as direct MR arthrography) or intravenously (referred to as indirect MR arthrography). Reported sensitivities for MR arthrography have ranged from 79 to 100%, and specificities have ranged from 85 to 100% [7–12]. Whether direct or indirect MR arthrography is preferred depends usually on the availability of fluoroscopy units and the training level of the performing radiologist, while patient acceptance has been shown to be similar for both shoulder MR imaging and MR arthrography [13].

In the past, most clinical studies that evaluated the accuracy of MR imaging or MR arthrography have been performed at single institutions with high-field and high-performance MR units using consistent MR imaging protocols. In addition, in these studies, MR images have usually been evaluated by radiologists sub-specializing in musculoskeletal radiology [5–12, 14]. These variables, which contribute to high-quality diagnoses, are often not present in the community setting. Thus, the diagnostic performance of MR imaging or MR arthrography examinations by community-based general radiologists is often viewed as being inferior to that of sub-specialist radiologists.

It is known from other radiological procedures such as breast ultrasound, computed tomography (CT) colonography or CT examinations for the detection of metastases of esophageal cancer that the experience of the radiologists can have a remarkable effect on the diagnostic performance [15–18]. Frequently, patients are referred to us from community-based orthopedic surgeons or general practitioners for further evaluation and treatment. In many patients prior MR imaging or MR arthrography has been performed by community-based general radiologists. In some patients, however, there were discrepancies between the MR findings described in the MR imaging reports and the findings of the clinical examination. In these cases, either MR images were re-evaluated by one of three experienced musculoskeletal radiologists or MR imaging/MR arthrography was repeated.

Based on these experiences, it was hypothesized that the overall diagnostic performance of MR imaging and MR arthrography of the shoulder depends on the training level of the performing radiologist. Specifically, we suspected a lower diagnostic performance for general radiologists compared with sub-specialist musculoskeletal radiologists. To the best of our knowledge, this has not been evaluated before. Thus, the purpose of our retrospective cross-sectional study was to evaluate the diagnostic performance of community-based general radiologists and sub-specialist musculoskeletal radiologists for the assessment of shoulder disorders with arthroscopic surgery as the reference standard.

Materials and methods

Study subjects

This retrospective study was carried out according to the Declaration of Helsinki. Written informed patient consent was waived by the institutional research ethics committee. The charts of all patients who underwent arthroscopic surgery of the shoulder between January 2002 and December 2004 were included and reviewed. We identified 238 patients (male, 175; female, 63; mean age, 40.4 years) in whom a total of 250 arthroscopic shoulder surgeries were performed. Eight patients underwent surgery of both shoulders (bilateral MR imaging or MR arthrography was performed prior to surgery) and 4 patients underwent revision surgery (MR imaging or MR arthrography was repeated after the initial surgery; Table 1). All patients underwent MR imaging or MR arthrography prior to surgery.

Magnetic resonance imaging

Magnetic resonance examinations were performed in 72 different community-based radiological institutions (MR images were evaluated by 72 different general radiologists with different levels of experience and different numbers of years of practice, but without sub-specialization in musculoskeletal radiology) or in the radiological institute of our hospital (MR images were evaluated by three different experienced fellowship-trained musculoskeletal radiologists). All institutions were equipped with similar high-field MR units (1.0 or 1.5 T) and multi-channel coil systems dedicated to shoulder imaging. MR imaging and MR arthrography protocols were not standardized among the different community-based radiological institutions. All MR arthrographies performed were direct arthrographies.

In total, 250 MR examinations of the shoulder were performed of which 55 (22%) were MR imaging examinations and 195 (78%) were MR arthrograms. Forty-eight MR imaging examinations were performed in community-based radiological institutions and 7 examinations were performed in our hospital. Of the 48 community-based MR imaging examinations, 28 (58%) were re-evaluated by one of the three different musculoskeletal radiologists at our hospital. The community-based general radiologists performed 57 of the 195 (29%) MR arthrograms of which 42 were re-evaluated (74%). One hundred and thirty-eight of the 195 (71%) MR arthrograms were performed at our

Table 1 Detailed overview of 250 arthroscopic surgeries performed in 238 patients

Procedure	Number of procedures
Shoulder arthroscopy, labral repair	112
Shoulder arthroscopy, labral repair, RC repair	46
Shoulder arthroscopy, RC repair	30
Shoulder arthroscopy, RC repair, biceps tenodesis	17
Shoulder arthroscopy, labral repair, RC debridement	7
Shoulder arthroscopy, labral repair, RC repair, biceps tenodesis	7
Shoulder arthroscopy, SAD, DCE	7
Shoulder arthroscopy, pericapsular release, RC repair, biceps tenodesis	5
Shoulder arthroscopy, labral repair, biceps tenodesis	4
Shoulder arthroscopy, labral debridement, RC repair	2
Shoulder arthroscopy, RC debridement	2
Shoulder arthroscopy, AC reconstruction	1
Shoulder arthroscopy, arthroscopy scapula	1
Shoulder arthroscopy, coracoid excision	1
Shoulder arthroscopy, labral debridement	1
Shoulder arthroscopy, labral debridement, biceps tenodesis	1
Shoulder arthroscopy, RC repair, pec major transfer, biceps tenodesis	1
Total	250

RC = rotator cuff; SAD = subacromial decompression; DCE = distal clavicle excision; AC = acromioclavicular; pec = pectoralis muscle.

hospital. The reports of all 250 MR examinations were available for review.

Arthroscopic surgery

Standard arthroscopic surgery as established at our hospital was performed by one fellowship-trained orthopedic surgeon with 15 years' experience in arthroscopic shoulder surgery (P.W.). During surgery, the shoulder joint was surveyed for pathologies of the labrum, bicipital complex, rotator cuff, and the humeral head, as well as of the subacromial space. Disorders of the aforementioned structures were documented in the surgical report as well as by representative arthroscopic images. The reports of all 250 arthroscopic surgeries were available for review.

Correlation of MR imaging and surgical findings

All MR imaging and surgical reports were reviewed and disorders of the labrum, bicipital complex, rotator cuff, and the humeral head, as well as of the subacromial space were recorded using the same criteria for both MR examinations and surgery. The labrum was graded as either normal or abnormal. Rotator cuff tears were divided into full thickness and bursal- and articular-sided partial thickness tears. MR findings consistent with intra-substance partial tears or tendinitis were considered to be normal, because these lesions may not completely be detected by arthroscopy. Biceps tendon tears were divided into partial and complete tears [19]. The humeral head was evaluated for Hill–Sachs lesions, which were graded as either present or not present.

Statistical analysis

Data were tabulated electronically using Excel® (Microsoft, Redmond, WA, USA). Statistical analysis was performed using SPSS® software (SPSS, Chicago, IL, USA).

Sensitivity, specificity, positive and negative predictive values, and accuracy of all MR examinations were calculated with respect to the above-mentioned disorders and with respect to whether the MR images were evaluated by a general or a specialist musculoskeletal radiologist. Therefore, cross tabulations were used after dichotomizing MR imaging/MR arthrography and surgical data into "normal" versus "abnormal".

A sub-analysis was performed for those cases in which initial MR imaging findings (as assessed by a community-based general radiologist) were inconsistent with the clinical findings during the physical examination and where MR images were re-evaluated pre-arthroscopically by one of the three specialists. The interobserver agreement between both readers was determined by calculating the Cohen kappa (κ) coefficient [20]. A κ value of 0–0.2 was considered to be indicative of a slight, 0.21–0.4 of a fair, 0.41–0.6 of a moderate, and 0.61–0.8 of a substantial agreement. Paired Student's t tests were used to determine any significant differences between the two readers. The significance level was considered to be $p=0.05$. Please note: all cases were with surgical proof.

Table 2 Diagnostic performance of unenhanced MR imaging of the shoulder

	General radiologists (number of cases = 48)					Musculoskeletal radiologists (number of cases = 7)				
Pathology	Sensitivity	Specificity	PPV	NPV	Accuracy	Sensitivity	Specificity	PPV	NPV	Accuracy
Labrum	29	92	67	71	70	20	33	50	66	43
Rotator cuff	93	60	88	75	85	50	0	83	0	71
Biceps	50	94	50	94	90	100	100	100	100	100
Hill–Sachs	0	85	n/a	100	85	0	100	0	100	100

All values are percentages unless otherwise stated.

PPV = positive predictive value; NPV = negative predictive value.

Results

The sensitivity of MR imaging was 29% (general radiologists) and 20% (musculoskeletal radiologists) for the detection of labral pathologies. Diagnostic performance was higher for the detection of rotator cuff tears and lesions of the bicipital complex (Table 2).

The diagnostic performance of MR arthrography of the shoulder was higher compared with unenhanced MR imaging (Table 3). Overall, maximum sensitivity for the general radiologists was 69% and that for the musculoskeletal radiologists was 94%. Specificities ranged from 83 to 100% (general radiologists) and from 93 to 100% (musculoskeletal radiologists).

Sub-analysis of those MR examinations that were re-evaluated showed that specialist radiologists performed better during the re-evaluation of MR images than the general radiologists during their initial image evaluation (Tables 4, 5). The interobserver agreement based on unenhanced MR imaging was κ=0.313, 0.467, 1.0, and 1.0 for the evaluation of labral pathologies, rotator cuff abnormalities, lesions of the bicipital complex, and the presence of Hill–Sachs defects. Student's *t* test analysis showed that observed differences in the interpretations of the labrum and rotator cuff between general and musculoskeletal radiologists were statistically significant (p=0.03, 0.03, 0.5, and 0.5). Corresponding kappa statistics for the evaluation of MR arthrograms revealed a weak agreement between both reader groups with κ values of 0.208, 0.396, 0.376, and 0.788 for labral pathologies, rotator cuff abnormalities, lesions of the bicipital complex, and Hill–Sachs defects respectively. The disagreement between readers was statistically significant for all evaluated disorders with the exception of the assessment of Hill–Sachs lesions (p=<0.001, 0.004, 0.019, 0.235).

Discussion

Our study tested the hypothesis that the overall diagnostic performance of MR imaging and MR arthrography of the shoulder depends on the training level of the performing radiologist. The results showed that, as suspected, the diagnostic performance of general radiologists is lower compared with sub-specialist musculoskeletal radiologists and that a significant difference in the interpretation of MR images can be observed between general and specialist radiologists [2].

When MR images were evaluated by sub-specialist musculoskeletal radiologists, sensitivities and specificities observed in our study for MR arthrography were in general within the range of the diagnostic performance reported in previous literature where, for example, a sensitivity of 89% and a specificity of 91% have been reported for the assessment of labral tears (our results: sensitivity 94%, specificity 71%) [21]. With regard to rotator cuff abnormalities, the performance of our specialists (sensitivity 84% and accuracy 90%) was also within the "normal" range reported in the literature where MR arthrography has

Table 3 Diagnostic performance of direct MR arthrographies of the shoulder

	General radiologists (number of cases = 57)					Musculoskeletal radiologists (number of cases = 138)				
Pathology	Sensitivity	Specificity	PPV	NPV	Accuracy	Sensitivity	Specificity	PPV	NPV	Accuracy
Labrum	69	100	100	33	73	94	71	90	81	88
Rotator cuff	67	83	86	63	73	84	93	88	91	90
Biceps	0	100	n/a	87	87	62	100	100	95	96
Hill–Sachs	50	100	100	93	93	70	99	88	97	97

All values are percentages unless otherwise stated.

PPV = positive predictive value; NPV = negative predictive value.

Table 4 Sub-analysis of unenhanced MR images re-evaluated by musculoskeletal radiologists: diagnostic performance of general radiologists versus musculoskeletal radiologists

Number of cases = 28	General radiologists					Musculoskeletal radiologists				
Pathology	Sensitivity	Specificity	PPV	NPV	Accuracy	Sensitivity	Specificity	PPV	NPV	Accuracy
Labrum	30	88	86	33	46	80	75	89	60	79
Rotator cuff	79	67	83	60	75	89	100	100	81	93
Biceps	67	100	100	96	96	67	100	100	96	96
Hill–Sachs	100	96	67	100	96	100	96	67	100	96

All values are percentages unless otherwise stated.

PPV = positive predictive value; NPV = negative predictive value.

proved to have a sensitivity of 83% and an accuracy of 90% [14]. Similar observations were made for the detection of bicipital complex abnormalities for which the observed accuracy of MR arthrography was 96% in our study (mean accuracy in the literature, 88% [12]).

General radiologists did not reach the level of diagnostic performance reported in previous literature [12, 14, 21]. Overall, their sensitivity for labral, rotator cuff, biceps, and humeral head abnormalities was found to be lower than the sensitivity for musculoskeletal radiologists (Table 3). General radiologists outperformed the specialists with regard to the specificity of the detection of labral abnormalities on MR arthrograms. The sub-specialized radiologists were both very sensitive and specific at the same time. This observation can be explained by the fact that at MR arthrography the intra-articular administered contrast agent not only distends the joint space but also outlines labral tears as they become filled with contrast solution [1]. Thus, it makes it easy to call a tear a tear when contrast is seen within the labrum. On the other hand, it remains difficult to detect tears that are not necessarily filled with contrast solution. Sub-specialist radiologists may be more sensitive in detecting all kinds of tears. However, as specificity increases, the specificity somewhat decreases.

The lack of intra-articular contrast might explain the low diagnostic performance of unenhanced MR imaging for the detection of labral pathologies. Sensitivities in our study were less than 29% for both general and musculoskeletal radiologists. The diagnostic performance was lower than in a previous study by Green Christensen where sensitivity of 79% was reported for the detection of labral abnormalities in patients with shoulder instability [6]. Other values were within the reported range of sensitivities and specificities for unenhanced MR imaging of the shoulder [2, 5–7]. Interestingly, the sub-specialist musculoskeletal radiologists could not outperform the general radiologists when unenhanced MR images of the shoulder were evaluated for labral abnormalities. This might be explained by the fact that our musculoskeletal radiologists prefer MR arthrography over unenhanced MR imaging for the evaluation of most shoulder abnormalities. Therefore, their experience in reading MR arthrograms is greater than their experience in reading unenhanced MR images.

We performed a sub-analysis of all cases in which MR images were re-evaluated by sub-specialized musculoskeletal radiologists. We found statistically significant differences in the interpretation of MR images between the general and the musculoskeletal radiologists, mostly with regard to labral and rotator cuff abnormalities. The overall interobserver agreement was only fair for these pathologies, and the specialists clearly outperformed the general radiologists when they re-evaluated the MR images. This comparison is, however, biased, because the musculoskeletal radiologists performing the re-evaluating were aware of

Table 5 Sub-analysis of MR arthrograms re-evaluated by musculoskeletal radiologists: diagnostic performance of general radiologists versus musculoskeletal radiologists

Number of cases = 42	General radiologists					Musculoskeletal radiologists				
Pathology	Sensitivity	Specificity	PPV	NPV	Accuracy	Sensitivity	Specificity	PPV	NPV	Accuracy
Labrum	44	90	93	33	55	84	100	100	67	88
Rotator cuff	60	70	53	76	67	87	92	87	93	90
Biceps	20	100	100	90	90	80	100	100	97	98
Hill–Sachs	50	100	100	95	95	75	100	100	97	98

All values are percentages unless otherwise stated.

PPV = positive predictive value; NPV = negative predictive value.

the fact that the initial MR reports made by the community-based general radiologists were inconsistent with the clinical findings. In addition, the general radiologists may have received none or less accurate clinical information (history, physical examination) than the musculoskeletal radiologists. Therefore, their re-evaluation might have been more thorough than usual, resulting in a more accurate interpretation of findings.

Inaccurate MR imaging findings can have a major effect on the diagnostic thinking and therapeutic decisions of orthopedic shoulder surgeons. Zanetti et al. have shown that in 49% of patients who underwent MR imaging, the therapeutic decision was changed [22]. In addition, a high diagnostic accuracy of any MR imaging examination is mandatory since the physical examination, when done properly by an experienced orthopedic surgeon, has proved to be highly sensitive (up to 90%) and specific (up to 85%) [4], especially when highly accurate diagnostic tests such as load-and-shift, sulcus, and provocative tests are used [23, 24].

Our study is not only limited by the above-mentioned biases, but also by its retrospective design, the patient selection bias inherent with this study design, and the fact that community-based MR imaging examinations were performed at 72 different radiological institutions without knowing the exact experience level of the radiologists. However, this reflects the daily routine clinical situation of a hospital-based specialized orthopedic surgeon to whom patients are referred from community-based surgeons or general practitioners who have already started the diagnostic work-up. Usually, the experience and years of practice of the radiologists involved are not known. Another important limitation of our study might be the fact that radiologists who closely work together with specialized surgeons, are biased by the general surgical approach and clinical thinking at their own hospital whereas the community-based radiologists are not. In other words, it is possible that radiologists and arthroscopists who work together learn to "converge" more frequently. Finally, our study is limited by the inclusion of four patients who underwent revision surgery. Although it is known that the diagnostic performance of MR imaging and MR arthrography is somewhat lower when performed in post-operative shoulders [9], we do not believe that this would have changed the overall findings of our study.

Conclusion

Our results indicate that the diagnostic performance of MR imaging and MR arthrography of the shoulder depends on the training level of the performing radiologist, with subspecialized musculoskeletal radiologists having better diagnostic performance than general radiologists.

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