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Original Article

The Diagnostic Value of Magnetic Resonance Imaging in Subacromial Impingement Syndrome

Murat Birtane[1], **Mustafa Çalış**[2], **Kenan Akgün**[3]

[1]*Department of Physical Medicine and Rehabilitation, Trakya University Faculty of Medicine, Edirne;*
[2]*Department of Physical Medicine and Rehabilitation, Erciyes University Faculty of Medicine, Kayseri;*
[3]*Department of Physical Medicine and Rehabilitation, İstanbul University Cerrahpaşa Faculty of Medicine, İstanbul, Turkey.*

The aim of this study was to assess the diagnostic ability of magnetic resonance imaging (MRI) in subacromial impingement syndrome (SIS), using a physiological standard of reference. MRI of the rotator cuff (RC) and subacromial injection test (SIT), a reference standard for SIS diagnosis, were performed in 125 painful shoulders. MRI diagnostic accuracies were determined using a 2 × 2 table and the percentage values of SIS diagnosis in patients with the three Zlatkin MRI stages were determined. Shoulder function was evaluated using the Constant Scale, and results were compared for stages. The sensitivity, specificity, accuracy, positive and negative predictive values of MRI for SIS diagnosis were 98.85%, 36.84%, 80%, 78.18% and 93.33% respectively. Of the 32 patients with Zlatkin stage 1 changes in MRI, 20 (62%) had SIT approved SIS diagnosis, while 47 (79%) of the 59 patients with Zlatkin 2 and all of the 19 (100%) patients with Zlatkin 3 changes were diagnosed with SIS by SIT. Mean Constant scores were 78.04 ± 18.3, 65.0 ± 19.9 and 54.52 ± 20.7 in patients with Zlatkin stages 1, 2 and 3, respectively ($p < 0.05$). The MRI of RC did not prove to be an excellent tool for SIT based SIS diagnosis, with its low specificity. However, the technique can give important clues, as its sensitivity and negative predictive values are high.

Key Words: Subacromial impingement syndrome, subacromial injection test, magnetic resonance imaging, function

INTRODUCTION

Subacromial impingement syndrome (SIS) is caused by the compression of suprahumeral structures, such as the rotator cuff (RC) muscles and the subacromial bursa underneath the anteroinferior aspect of the acromion and coracoacromial ligament, leading to pain and shoulder dysfunction mainly in with respect to forward flexion, abduction and the external rotation of the shoulder.[1-3] SIS leads to progressive oedema, fibrosis and consequent tears in the RC muscles, which were categorised in 3 stages by Neer.[4-6] Stage 1 is characterised by oedema and haemorrhage. In stage 2 cuff fibrosis is evident, with thickening and partial cuff tearing. Stage 3 involves the specific findings of full thickness tendon tears, bony changes and tendon ruptures.

Magnetic resonance imaging (MRI) has been found to be an excellent non-invasive tool for the diagnosis of these lesions by some authors.[7] This imaging method has been reported to demonstrate effectively the soft tissue lesions associated with SIS, which include subdeltoid bursitis, supraspinatus tendinopathy and RC tendon tears.[8] On the other hand, some authors have reported upon the low sensitivity and specificity of MRI for partial RC tears using arthroscopic and cadaveric specimens, respectively.[9,10] These standard reference methods mainly evaluate the anatomopathologic conditions in RC and the surrounding structures. It has also been shown that a significant number of asymptomatic shoulders may also reveal abnormal internal signals and even complete ruptures of RC tendons, by MRI.[11,12] In a study, Frost et al.[13] investigated whether RC pathology, as demonstrated by MRI, is associated with the clinical signs of SIS. They reported that age was related to MRI based supraspinatus

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Reprint address: request to Dr. Murat Birtane, Kocasinan Mah. 6. Sok. Akan 3 Apt. No: 1, Daire 4, 22030 Edirne-Turkey. Tel: 90-284-2357641-1080 or 90-284-2359187, Fax: 90-284-2359187, E-mail: mbirtane@hotmail.com

pathology more so than clinical signs of impingement.

In this study we assessed the diagnostic ability of MRI in SIS using a physiological reference standard namely the subacromial injection test (SIT). SIT does not investigate the anatomopathologic condition in RC, but depresses the pain generators in the subacromial area where the impingement occurs.[5,14] Thus clinical symptoms of SIS are relieved, and a marked relief of pain and an improvement in passive and/or active shoulder movements after SIT suggest that the test is positive and that the pain generator is SIS. We also assessed the ability of Zlatkin MRI stages[15] in terms of SIS diagnosis, and finally, we compared the shoulder functions of SIS patients with different Zlatkin MRI stages.

MATERIALS AND METHODS

Patient selection

One hundred and twenty-five shoulders in 120 consecutive patients with shoulder pain, referred from orthopaedic surgery and rheumatology polyclinics to our Physical Therapy and Rehabilitation Department were evaluated in this study. Patient characteristics with respect to age and gender were noted. Addition detailed physical examinations and laboratory tests were performed to identify patients unsuitable for study. Exclusion criteria were as follows: 1) inflammatory or systemic diseases with shoulder involvement, 2) acute traumatic conditions, 3) postoperative conditions 4) neck or elbow disorders.

Diagnosis

We performed SIT as a standard of reference for discriminating whether the source of pain was SIS or not. 10 cc of one percent lidocaine was injected into the subacromial space under acromion using an anterior approach. The introduction of the needle was assisted by gentle longitudinal traction on the arm to widen the gap between the acromion and the humeral head. The needle was placed below the anterior edge of acromion. Special attention was paid not to inject the lidocaine into the tendon or the glenohumeral joint. Marked relief of pain and an almost total improvement in the passive and/or the active range of motion (ROM), 30 minutes after injection suggested that the test was positive and if no calcific deposits were present on radiographs, a final diagnosis of SIS was made.

MRI evaluation

Besides plain radiographic evaluation, MRI was performed using a one tesla device (Somatom Impact, Siemens, Erlangen, Germany) for all patients. The patients were placed in a supine position and the shoulder to be imaged was fixed by a shoulder coil during the imaging procedure. Sagittal proton density-weighted (PD-W) and T2-weighted (W), coronal oblique T1-W, T2-W and PD-W images using fast spin echo sequence and axial images using gradient echo sequence were obtained. Images were obtained using a FOV (field of view) of 16 - 19 cm, a matrix of 192 - 200 × 192 - 256, at an acquisition time of 1 - 2 msec. and with a 4 mm slice thickness. Duration of the imaging investigation was 30 minutes for each patient. The pathologic changes in RC tendons were classified, according to Zlatkin's[15] MRI stages of SIS, by an experienced radiologist, as follows: Stage 0: tendon morphology and signal intensity normal. Stage 1: increased signal intensity in the tendon without any thinning irregularity or discontinuity (Fig. 1). Stage 2:

Fig. 1. Coronal oblique section (TR=620, TE=15). The supraspinatus tendon shows diffuse high signal intensity with normal morphology and no evidence of discontinuity (Zlatkin 1 MRI stage).

increased signal intensity with irregularity and thinning of the tendon (Fig. 2). Stage 3: complete disruption of the supraspinatus tendon. Patients with stage 1 MRI findings and above were accepted as MRI positive cases for SIS (Fig. 3). Here stage 1 changes were discriminated from the magic angle effect when the hyperintensity was observed only in the T1W slices, and not in the T2W and PD-W slices.

Functional evaluation

Shoulder functions in the patients were evaluated by Constant Scale before subacromial injection.16 This scale evaluates overall shoulder function on 100 points. Shoulder pain, as a subsection of this analysis, was evaluated on 10 points, daily living activities as 20 points, the active range of motion as 40 points and strength on 25 points.

Fig. 2. Coronal oblique section (TR=3500, TE=90). Increased signal intensity with irregularity and thinning in the supraspinatus tendon (Zlatkin 2 MRI stage).

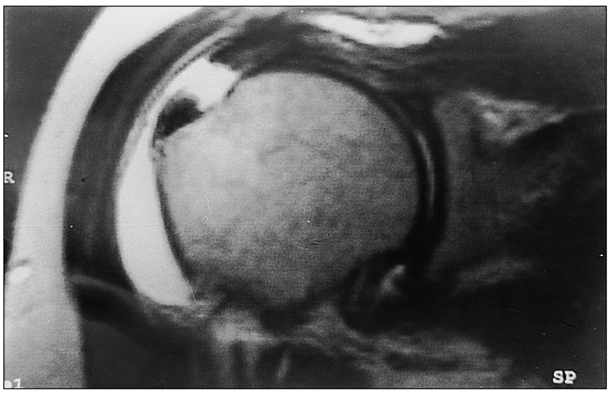

Fig. 3. Coronal oblique section (TR=3500, TE=90). The supraspinatus tendon is discontinuous, with associated retraction of the supraspinatus muscle. (Zlatkin 3 MRI stage).

Analysis

Sensitivity, specificity and confidence interval values of MRI for SIS diagnosis were calculated using a 2 $\times$ 2 table. In addition, the ratio of SIS patients in each of the Zlatkin MRI stages were separately identified, and comparisons among the groups were made by Chi square analysis. Age and functional status of shoulders with various Zlatkin stages of MRI were compared using the Kruskal Wallis Anova test.

RESULTS

Of the 120 patients enrolled, 72 (60%) were female and 48 (40%) were male. The average age of the whole patient group was found to be 51.60 $\pm$ 13.9 (Min. age :18, max. age: 70). Eighty-six of the 120 (68.8%) patients reacted positively to SIT, and thus formed the SIS group. One patient in this group had bilateral shoulder pain. Two SIT positive shoulders were not accepted in the SIS group, as calcific deposits were observed in their radiographs. With the appropriate diagnostic techniques, 19 adhesive capsulitis, 7 calcific tendinitis, 6 myofascial pain syndrome, 3 glenohumeral arthrosis, 2 thoracic outlet syndrome and 1 primary bicipital tendinitis were diagnosed in 34 patients who reacted negatively to SIT. Four patients had bilateral pain in this group. The MRIs of 15 shoulders revealed normal RC morphology, and 110 shoulders showed abnormal signal intensity. The numbers and percentages of shoulders with a SIS or a non-SIS diagnosis according to the SIT test and MRI findings are summarised in Table 1.

The sensitivity, specificity, accuracy, positive (PPV) and negative predictive values (NPV) of MRI as a whole, for SIS diagnosis were 98.85%, 36.84%, 80%, 78.18% and 93.33% respectively, as shown in Table 2.

The distribution of MRI based pathologic shoulders among the Zlatkin MRI stages and the ratio of patients with SIT approved SIS in each of

Table 1. The Distribution of Painful Shoulders with Subacromial Impingement Syndrome, According to Subacromial Injection Testing and Magnetic Resonance Imaging

	According to subacromial injection testing		According to magnetic resonance imaging	
	Number	%	Number	%
SIS shoulders	87	(69.6%)	110	(88%)
Non SIS shoulders	38	(30.4%)	15	(12%)
Total	125	(100%)	125	(100%)

Table 2. Sensitivity, Specificity, Accuracy and Predictive Values of Magnetic Resonance Imaging for Subacromial Impingement Syndrome

	Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
MRI	86/87 (98.85%)	14/38 (36.84%)	100/125 (80%)	86/110 (78.18%)	14/15 (93.33%)

Table 3. The Distribution of Age and Percentage Values of Subacromial Impingement Syndrome Diagnosis among Zlatkin Stages

	Number (%)	Mean age (± SD)	SIT approved SIS Number & (%)	Mean constant scores in SIT approved SIS patients
Zlatkin stage 1	32 (29.1%)	42.21 ± 13.5	20 (62%)	78.04 ± 18.3
Zlatkin stage 2	59 (53.6%)	55.88 ± 10.1	47 (79%)	65.0 ± 19.9
Zlatkin stage 3	19 (17.3)	61.4 ± 10.5*	19 (100%)†	54.52 ± 20.7‡

*Zlatkin 1 < Zlakin 2 < Zlatkin 3 (Kruskal Wallis Anova test).
†Zlatkin 1 = Zlatkin 2 < Zlakin 3 (Chi square test).
‡Zlatkin 1 > Zlatkin 2 > Zlatkin3 (Kruskal Wallis Anova test).

the stages are shown in Table 3. The ratio of SIT patients increased as the stages advanced, and the difference between stages in this respect reached statistically significant values between stage 3 and the other two stages. The mean ages of the patients in these stages were also demonstrated. Mean ages increased in parallel with the stages and were significantly different among them ($p < 0.05$) (Table 3).

Shoulder function seemed to deteriorate with increased MRI stages. Mean Constant scores, in SIT approved SIS patients within Zlatkin stages of 1, 2 and 3 are shown in Table 3. Shoulder functions of the patients with advanced stages was significantly worse ($p < 0.05$).

DISCUSSION

The ability of MRI to demonstrate the pathologies of RC muscles and tendons caused by impingement between the humeral head and the coracoacromial arch, has been controversial. Iannotti et al.[7] reported that MRI could demonstrate complete tears with 100% sensitivity and 95% specificity, and observed a sensitivity of 87% and a specificity of % 93 for MRI, in the differentiation of normal tendon from tendinitis. They concluded that high resolution MRI seemed to be an excellent tool for diagnosing RC lesions, and this finding has been reinforced by more recent studies.[17,18] In another experimental study on cadaveric joint specimens, Bachmann[10] found that MRI discriminated abnormal cuff tendons and normal cuff tendons with 96% sensitivity and % 100 specificity. Moreover, Nelson et al.[19] reported MRI to be the most useful modality for establishing the etiology of pain due to impinged RC lesions, in a study which compared the results of various imaging techniques and operative findings. Similarly Uri[20] reported that MRI was the most favourable imaging tool in the diagnosis of RC pathologies as it provided anatomic information in combination with superior soft-tissue contrast visualization.

On the other hand Torstensen,[21] using arthroscopy, suggested that RC tears can be identified with an accuracy of 68%, a sensitivity of 96% and a specificity of 49% by MRI. The author concluded that MRI does not appear to be an accurate tool for assessing shoulder pathologic conditions when the clinical picture ambiguous. In addition, many MRI studies have raised a common point of concern concerning the technique's inability to depict partial tears as accurately as it does complete tears.[22,23] In a recent study, using surgical findings as gold standard, Kenn et al.[24] reported the sensitivity and specificity values of MRI to be 92% and 93%, respectively, for the diagnosis of complete tears, and reported the same parameters as to be 69% and 86%, respectively, for incomplete tears.

All of the studies above seemed to investigate the ability of MRI to depict the anatomopathologic findings shown in reference standard diagnostic techniques like arthroscopy, surgery and cadaveric specimen studies. However, these anatomopathologic pathologies may exist even in asymptomatic shoulders. In a study that evaluated MRI findings in symptom-free shoulders, 30% of RC tendons were determined to have abnormal internal signals.[11] In recent trials, even complete ruptures were shown in asymptomatic shoulders, especially in elderly people.[12] This data suggests that the RC lesions as shown on MRI may not be associated with the clinical symptomatology of SIS. Thus we used SIT in this study to resolve this issue.

The injection of a local anaesthetic into the subacromial space usually relieves all of the patients' pain in SIS according to Burkhead et al[25]. Neer[5,14] identified SIT in his reports, as a most useful method of separating impingement lesions from other causes of shoulder pain, as did other authors who defined SIT as being very important and helpful in SIS diagnosis.[26,27] Despite the absence of validation studies on SIT, we preferred this appreciated test as a reference standard for SIS diagnosis. The principle behind SIT involves specific pain relief and ROM improvement when an anaesthetic agent is administered into the subacromial space, which is the locus of SIS pathology,[3,5,14] if the source of shoulder pain involves the impingement of RC in this area. However, shoulders with calcific bursitis and/or calcific tendinitis may also react positively to SIT. As these clinical pictures are separated from SIS by the definition of Neer,[14] we excluded 2 SIT positive shoulders, as we observed calcific deposits in their radiographs.

We found high sensitivity with low specificity for MRI based pathologic findings in terms of discriminating SIT based SIS diagnosis. This result is consistent with the report of Torstensen[21] who reported that MRI is highly sensitive, but shows low specificity for SIS diagnosis. Under these circumstances it is logical to suppose that MRI can demonstrate pathologic RC signs, in shoulder pathologies other than SIS. Moreover, MRI identified pathologic RC lesions did not necessarily seem to generate pain. However, when the MRI is normal, there is a high probability that the diagnosis will not be SIS as we found the negative predictive value of MRI to be high.

The percentage values of SIT approved painful SIS patients were observed to increase as the Zlatkin MRI stages advanced, which showed that the probability of SIS diagnosis increases as the MRI staging increases. The most striking result in the evaluation of Zlatkin MRI stages was that we obtained a percentage value of 100% for the existence of SIS diagnosis in patients with Zlatkin stage 3 MRI findings. Despite the fact that some earlier reports have suggested that even complete ruptures in RC tendons may be asymptomatic, our findings suggests that the diagnosis of such pathology will be painful SIS. Similarly, if the MRI findings of the shoulder indicate stage 3 changes, unless a coincidental involvement occurs, the diagnosis will be SIS. Likewise many other studies have reported that MRI is highly specific for complete RC tears.[7,22-24,28] The percentage value that we found is valid for painful SIS as diagnosed using SIT as a reference test, although, this striking result for complete stage 3 tears in our study may be due to the relatively small number of patients with Zlatkin stage 3 changes.

MRI not only assesses the pathologic conditions in RC directly, but also in surrounding structures, which influence the diagnosis of SIS. For example, complete RC tears were found to be related to, a peribursal fat plane, subacromial distance, acromion shape, subacromial osteophytic spurs and subdeltoid bursal fluid, as shown by MRI.[8,29,30] Taking these findings into account may increase the diagnostic ability of MRI, moreover, MRI of painful shoulder is also important in the discrimination of neoplasms and fractures.[2]

The age of the patients increased and the shoulder function decreased as the Zlatkin stages advanced, reflecting the progressive character of SIS, which begins during youth, and causes progressively deteriorating functions to climax in stage 3.

In conclusion, MRI of RC is not excellent tool for painful SIS diagnosis, because of its low specificity, from a SIT based diagnostic point of view. However, it may give some important diagnostic clues, as its sensitivity and negative predictive values are high. Moreover, Zlatkin stage 3 changes in MRI appear to be very helpful for the correct diagnosis of SIS. In addition indirect MRI findings in SIS may be helpful in the differential diagnosis of neoplasms and fractures.

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