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RESEARCH ARTICLE

Shoulder Impingement Syndrome

Relationships Between Clinical, Functional, and Radiologic Findings

ABSTRACT

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Objective: Although there has been much research about imaging methods for shoulder impingement syndrome, the clinical information and upper limb level of disability have been generally ignored. The purpose of this study was to detect the relationships between clinical, functional, and radiologic variables in patients with shoulder impingement syndrome.

Design: A cross-sectional, clinical, and radiologic study was planned and 59 shoulders of 58 consecutive patients waiting for physical therapy because of a clinically suspected shoulder impingement syndrome were included into this study. Comprehensive clinical examination, radiography, shoulder ultrasonography, and magnetic resonance imaging were performed in the same month.

Results: Despite the high sensitivities of ultrasonography for diagnosing rotator cuff tears (98.1%) and biceps pathologies (100%), magnetic resonance imaging was superior to ultrasonography in many important shoulder structures such as a glenoid labral tear and subacromial bursal effusion/hypertrophy ($P < 0.01$). These structures were the determinants of the shoulder's disability measured by disabilities of the arm, shoulder, and hand questionnaire.

Conclusion: Ultrasonography and magnetic resonance imaging had comparable high accuracy for identifying the biceps pathologies and rotator cuff tears. The basic clinical tests had modest accuracy in both disorders. The choice of which imaging test to perform should be based on the patient's clinical information (regarding lesion of glenoid labrum, joint capsule, muscle, and bone), cost, and imaging experience of the radiology department.

Key Words: Shoulder Impingement Syndrome, Ultrasonography, Magnetic Resonance Imaging, Shoulder Disability

Shoulder impingement syndrome (SIS) is the most common disorder of the shoulder, resulting in functional loss and disability in the patients it affects. Neer's impingement concept depicted the syndrome as a lifelong process with three stages.[1] Critical hypovascular zones were described in both the supraspinatus and infraspinatus tendons, and repetitive microtraumatic motions or overuses are the risk factors for these regions.[2] In addition to the patient history, physical examination findings, and specific impingement test maneuvers, radiologic evaluation may be necessary for selected patients that are unresponsive to conservative treatment and have the probability of surgical procedure. Routine radiographs may show the shape of acromion and changes in acromioclavicular and glenohumeral joints but have no value in soft-tissue changes seen in SIS.[3–5] However, both detection and quantification of the rotator cuff tear could provide guidance with regard to operative indication and prognosis and to which type of operative procedure should be recommended.[6] Although ultrasonography and magnetic resonance imaging (MRI) have been reported to be highly accurate for the detection of rotator cuff lesions in different studies,[6–17] three studies demonstrated poor results of ultrasonography.[15–17] Clinical and radiologic correlations were lacking in these studies, and patients' disability and quality-of-life issues were generally ignored, despite their critical importance. This is the first clinical, functional, and radiologic study about SIS that has also evaluated the functional status of the upper limb.

The purpose of this study was to detect the relationships between clinical, functional, and radiologic diagnostic (ultrasonography, MRI) measures in patients with SIS and to compare the diagnostic performances of ultrasonography and MRI. MRI has been used as the gold standard because our patients did not want arthroscopic evaluation.

PATIENTS AND METHODS

Patient Selection and Study Design

Patients with SIS were randomly selected from the Department of Physical Medicine and Rehabilitation I, Ankara Education and Research Hospital, between November 2002 and July 2004. After the approval of the Institutional Review Board of Ankara Education and Research Hospital, 58 patients (45 women and 13 men) waiting for physical therapy because of a clinically suspected SIS were asked to participate in the study and gave informed consent. In addition to history of chronic shoulder pain, comprehensive clinical examination including active range of motion and special tests for instability, impingement, labral tears, scapular stability, and muscle/tendon pathologies were used for patient selection.[18] Patients that had no history of trauma and had shoulder pain of >3 mos, were unresponsive to analgesic medication after 3 wks, and had a diagnosis of suspected SIS were admitted to this study. Patients with history of shoulder and cervical trauma, cervical discopathy, neurologic origin of muscle weakness, and additional musculoskeletal problems of an upper limb were excluded from this study. In addition, patients with systemic, metabolic, or inflammatory diseases or contraindications to perform ultrasonography or MRI were also excluded.

Clinical Evaluation

The same physician (G. Findikoglu) examined each patient. All patients were right-handed and had noninflammatory symptoms of the shoulder, with a mean duration of 11.8 mos (range, 4–84 mos). The mean age of all patients was 55.5 yrs (SD, 12.4 yrs). Reported pain score on the 10-cm visual analog scale, active shoulder range of motion values, pain at isometric resisted movement, and the score on the disability of arm, shoulder, and hand (DASH)[19] were recorded in all patients. Neer[20] and Hawkins-Kennedy[21] tests were used as impingement maneuvers. A positive Neer impingement sign is present if pain and its resulting facial expression are produced when the arm is forcibly flexed forward by the examiner, jamming the greater tuberosity against the anteroinferior surface of the acromion. Alternatively, the Hawkins-Kennedy impingement test demonstrates the impingement sign by forcibly medially rotating the proximal humerus when the arm is forward flexed to 90 degrees. In addition, the Speed's test (biceps or straight-arm test) was also used for the evaluation of the biceps tendon.[22] This test is performed by forward flexing the patient's arm to 90 degrees and then asking the patient to resist an eccentric movement into extension first with the arm supinated and then pronated. A positive Speed's test elicits increased tenderness in the bicipital groove, especially with the arm supinated, and is indicative of bicipital paratendonitis or tendinosis.

Radiologic Evaluation

All patients had AP and axillary shoulder radiographs within normal limits. Radiologic evaluation was done during the same month after admission for clinical examination.

Ultrasonography was performed by the first experienced musculoskeletal ultrasonography radiologist (M. Kacar), who was unaware of the patient's history or findings of the physical examination. The ultrasonographic transducer was the 7.5-MHz linear array and 5-MHz curved array (Hitachi

EUB 420, Tokyo, Japan). The 7.5-MHz linear-array transducer is usually the first choice for shoulder ultrasonography. However, in the present study, the 5-MHz curved-array transducer was also used for two images: the overview of the infraspinatus tendon on longitudinal view of the dorsal aspect of the shoulder and the joint capsule at the humeral head/shaft seen at the axilla. Because of the slightly less superficial structures to be visualized and the anatomic shape of the axilla, the 5-MHz curved-array transducer was used. During ultrasonographic examination, the patients were seated on a stool and the radiologist (M. Kacar) stood behind the patient during the scan. Ultrasonography of the shoulder begins with a transverse and longitudinal image of the biceps tendon within the bicipital groove. Next, longitudinal and transverse scans of the subscapularis tendon are made with the patient's arm externally rotated. Images of the supraspinatus tendon are made with the arm in internal rotation to expose as much of the supraspinatus tendon as possible from beneath the acromion. This position is best achieved by placing the patient's arm behind his or her back. The supraspinatus tendon may be scanned perpendicular and parallel to its fibers. The thickness and echogenicity of the tendon, the segmental or complete loss of rotator cuff substance, the presence and amount of joint and bursal fluid, the loss of convex contour of the tendon on the bursal side, and greater tuberosity changes are observed. In addition, it is important to use the transducer to compress the deltoid muscle against the cuff in an attempt to separate the torn tendon ends at the site of a nonretracted tear. The standardized ultrasonographic criteria for rotator cuff evaluation were used in each patient.[23] We added scores to the criteria of van Holsbeck and Introcaso[23] for full-thickness rotator cuff tears: a discontinuity in the rotator cuff (scored as 1) and extension from the bursal to the humeral side of the rotator cuff (scored as 2). Other detected ultrasonographic findings (subacromial bursal effusion/hypertrophy, biceps rupture, biceps effusion/hypertrophy, incomplete tear of the supraspinatus, glenohumeral effusion/hypertrophy) were graded as minimal (scored as 1), moderate (scored as 2), and marked (scored as 3).

MRI was performed in the same month as ultrasonography admission with a 0.5T system (GE, Milwaukee, WI) with a dedicated shoulder coil as receiver. All patients were placed supine in the system. After a T1-weighted (repetition time/echo time of 680/15 msecs) localizing sequence, a standard T2-coronal spin-echo sequence (repetition time/echo time of 3000/15.105 msecs) was performed. Oblique coronal images were available for scoring. The following imaging variables were used: section thickness of 3 mm, with a 1-mm gap, matrix of 128 $\times$ 256, field of 4–8 mins per sequence, with a total examination time of 45 mins. A complete rotator cuff tear was defined as a focal, well-defined area of increased signal intensity on T1-weighted and T2-weighted images that extended through the entire thickness of tendon. The images were evaluated by the second experienced musculoskeletal radiologist (M. C. Kahraman), who was not aware of either the clinical status of the patient or the results of ultrasonography. All tears observed are described as follows. Full-thickness or complete tears are distinguished from incomplete tears. Complete tears are either focal (scoring as 1), subtotal (scoring as 2), or total (scoring as 3). Focal tears display a piercing tendon hole; in subtotal tears, only a few fibers are regularly inserted, whereas in total tears, all tendon fibers are torn and the stump is retracted under the acromion. Incomplete tears are either intratendinous (scored as 1) or partial (scored as 2). In intratendinous tears, the split is only within the tendon itself. In partial tears, some tendinous fibers on the articular or bursal surface are interrupted. Other MRI findings (subacromial bursal effusion/hypertrophy, biceps rupture, biceps effusion/hypertrophy, glenohumeral effusion/hypertrophy, glenoid labral tear, greater tuberositas erosion, anteromedial erosion, and posterolateral erosion) were graded as minimal (scored as 1), moderate (scored as 2), and marked (scored as 3).

Statistical Analysis

SPSS 11.0 statistical software (Chicago, IL) was used for all statistical analyses. K-related samples, χ^2, and Kendall's W (coefficient of concordance) nonparametric tests were selected for comparison of the ultrasonographic and MRI findings. We accepted MRI as the gold standard. After that, calculations were performed to determine sensitivity and specificity of selected clinical tests and ultrasonographic findings. These calculations were performed by considering both a complete and an incomplete tear as a tear. The true-positive, true-negative, false-positive, and false-negative cases in using both impingement maneuvers and ultrasonographic evaluation of rotator cuff tears were recorded. The true and false, positive and negative cases for Speed's test and ultrasonographically detected bicipital pathologies were also recorded. Ninety-five–percent confidence intervals were calculated for the predictive values, kappa values for the comparisons between the results of the clinical examination and the ultrasonographic tests were determined, and McNemar tests were used to test for significant differences between the diagnoses made with the clinical and ultrasonographic results. In addition, multiple correlation analyses were made between clinical and radiologic variables using Pearson's correlation proximity matrix. After that, logistic regression analyses were applied to detect radiologic determinants of the shoulder disability.

RESULTS

Clinical Results

The clinical evaluation findings of 39 right (66.1%) and 20 left (33.9%) shoulders in 58 patients (one patient had bilateral SIS) with SIS are shown in Table 1. Active shoulder abduction values were more restricted than those of flexion. Both internal and external rotation values were similarly and mostly restricted in these patients, as had been expected. Most of the patients reported pain at isometric resisted internal rotation and abduction movement of their shoulder joints.

Radiologic Results

Radiographic measures of all patient shoulders were within normal limits. Type III acromion and abnormalities such as degenerative changes in both acromioclavicular and glenohumeral joints were not detected. The comparison of ultrasonographic and MRI findings are shown in Table 2. MRI was superior to ultrasonography in many shoulder structures, except for biceps lesions ($P < 0.01$). Surprisingly, 71% of patients had a complete supraspinatus tear and 44% of them had a glenoid labral tear on MRI. Ultrasonography could not detect glenoid labral tears, greater tuberositas, and posterolateral erosions in any patient. However, these could be detected on MRI. Ultrasonographic and MRI scans of the same patients with bicipital tendonitis are shown in Figure 1 and Figure 2, respectively. Inflammation in both biceps and supraspinatus tendons were marked on MRI, but only biceps tendonitis was detected on ultrasonography.

TABLE 1. Clinical evaluation findings in the 59 shoulders of 58 patients

	Mean ± SD	Range
Age, yrs	55.5 ± 12.4	38–80
Time of shoulder pain, mos	11.8 ± 7	4–48
VAS pain score (scale of 0–10)	7.5 ± 2.1	2–10
Functional score of DASH, %	58.3 ± 24.8	6–97
Active shoulder ROM, degrees		
Flexion	139.2 ± 24.5	90–180
Extension	52.3 ± 14.2	20–75
Abduction	119.3 ± 25.5	60–170
Adduction	32.5 ± 10.8	20–60
External rotation	53.0 ± 21.6	0–90
Internal rotation	50.7 ± 18.2	5–90
Pain with resisted isometric motion	%	*n*
Flexion	74.6	44
Extension	44.1	26
Abduction	84.7	50
Adduction	74.6	44
External rotation	77.9	46
Internal rotation	88.1	52
Impingement maneuvers	71.2	42
Speed's test for biceps	37.3	22

VAS, visual analog scale; ROM, range of motion; DASH, disability of arm, shoulder, and hand.

Clinical and Radiologic Correlations

There were many important clinical and MRI correlations. Reported severity of shoulder disability was correlated with subacromial bursal effusion ($r = 0.4, P = 0.03$) and glenoid labral tear ($r = 0.5, P = 0.02$) on MRI and restricted extension movement of shoulder ($r = -0.3, P = 0.03$). More painful shoulders had more frequent glenoid labral tears ($r = 0.8, P = 0.00$) on MRI and more restricted extension movement of the shoulder ($r = -0.6, P = 0.01$). Impingement test maneuvers ($r = 0.8, P = 0.00$), glenoid labral tear ($r = 0.6, P = 0.01$), and anteromedial erosion ($r = 0.5, P = 0.02$) findings on MRI were more prominent in patients with dominant hand involvement.

The glenoid labral tear finding on MRI was detected in 44.1% of patients and correlated with shoulder pain ($r = 0.8, P = 0.00$) and disability ($r = 0.6, P = 0.02$), pain at adduction ($r = 0.4, P = 0.03$), and restricted external rotation ($r = -0.4, P = 0.02$).

Subacromial bursal effusion/hypertrophy on MRI was detected in 37.3% of patients and also correlated with shoulder disability ($r = 0.5, P = 0.03$) and impingement test maneuvers ($r = 0.3, P = 0.04$).

The complete tear of the supraspinatus tendon on MRI was detected in 71.2% of patients and correlated with impingement test maneuvers ($r = 0.3, P = 0.05$) and restricted shoulder internal rotation ($r = 0.5, P = 0.02$). Similarly, incomplete tear of the supraspinatus tendon on MRI was detected in 27.1% of patients and correlated with impingement test maneuvers ($r = 0.2, P = 0.05$).

The anteromedial erosion on MRI was detected in 30.5% of patients and correlated with restricted shoulder internal rotation ($r = -0.7, P = 0.00$) and pain at both internal and external rotation ($r = 0.4, P = 0.02$).

When we analyzed the clinical and ultrasonographic findings of the shoulder, we detected fewer correlations compared with the correlations between clinical and MRI findings. The subacromial bursal effusion/hypertrophy on ultrasonography was detected in 16.9% of patients and correlated with restricted shoulder internal rotation ($r = -0.4, P = 0.02$) and pain at shoulder extension ($r = 0.3, P = 0.03$). The complete supraspinatus tear on ultrasonography (54.2%) correlated with only

TABLE 2. Comparisons of the frequencies between shoulder ultrasonographic findings and magnetic resonance imaging (MRI) findings

	Ultrasonography	MRI	P
Bursal effusion/hypertrophy	16.9% (n = 10)	37.3% (n = 22)	<0.05[a]
Biceps rupture	3.4% (n = 2)	3.4% (n = 2)	>0.05
Biceps effusion/hypertrophy	57.6% (n = 34)	57.6% (n = 34)	>0.05
Incomplete tears of the supraspinatus	54.2% (n = 32)	71.2% (n = 42)	<0.05[a]
Complete tears of the supraspinatus	37.3% (n = 22)	27.1% (n = 16)	<0.05[a]
Tears of the supraspinatus	91.5% (n = 54)	98.3% (n = 58)	>0.05
Glenohumeral effusion/ hypertrophy	6.8% (n = 4)	33.9% (n = 20)	<0.05[a]
Glenoid labral tear	0% (n = 0)	44.1% (n = 26)	<0.05[a]
Greater tuberositas erosion	0% (n = 0)	13.6% (n = 8)	<0.05[a]
Anteromedial erosion	6.8% (n = 4)	30.5% (n = 18)	<0.05[a]
Posterolateral erosion	0% (n = 0)	27.1% (n = 16)	<0.05[a]

[a] Statistically significant differences.

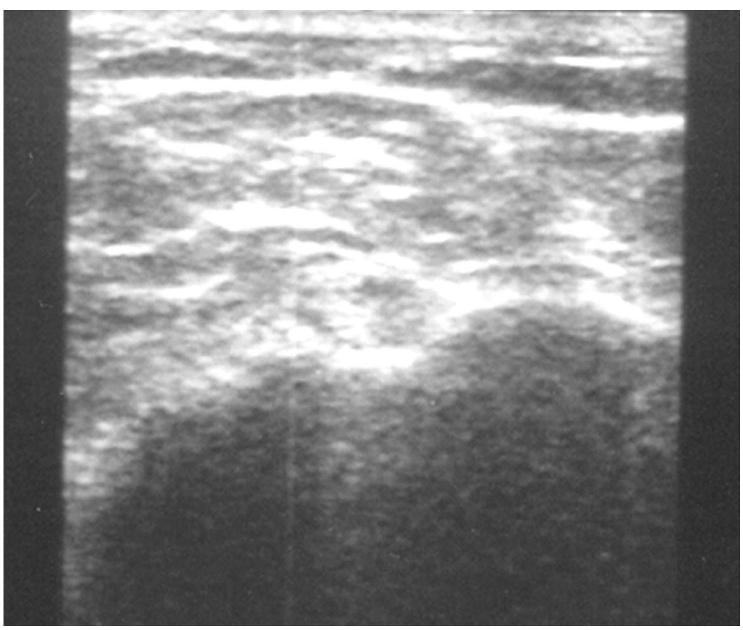

FIGURE 1 *Ultrasonographic appearance of biceps tendonitis with minimal fluid collection in synovial sheath of biceps tendon (used with written permission of the patient).*

pain at shoulder adduction ($r = 0.2, P = 0.04$). The incomplete supraspinatus tear on ultrasonography (37.3%) correlated with pain at both internal ($r = 0.4, P = 0.04$) and external rotation ($r = 0.3, P = 0.02$) of the shoulder.

After applying logistic regression analyses, it was found that only glenoid labral tear and bursal effusion/hypertrophy on MRI were determinants of shoulder disability. Predictive values for clinical examination findings, including impingement test maneuvers and Speed's test, and ultrasonographic findings in the diagnosis of complete or incomplete rotator cuff tears and biceps pathologies, including biceps rupture and biceps effusion/hypertrophy, are shown in Table 3. Both the sensitivity and the specificity of ultrasonography (100%) were higher than Speed's test (69.2% and 60%) and equal to MRI in biceps pathologies. The sensitivities were high (98.1% and 78.3%) for both ultrasonography and impingement test maneuvers, but the specificities of ultrasonography (60%) and impingement test maneuvers (50%) were only modest for both tests to detect supraspinatus tears. Ultrasonography underestimated complete supraspinatus tears in ten cases with MRI verification (54.2% *vs.* 71.2%) and overestimated incomplete supraspina-

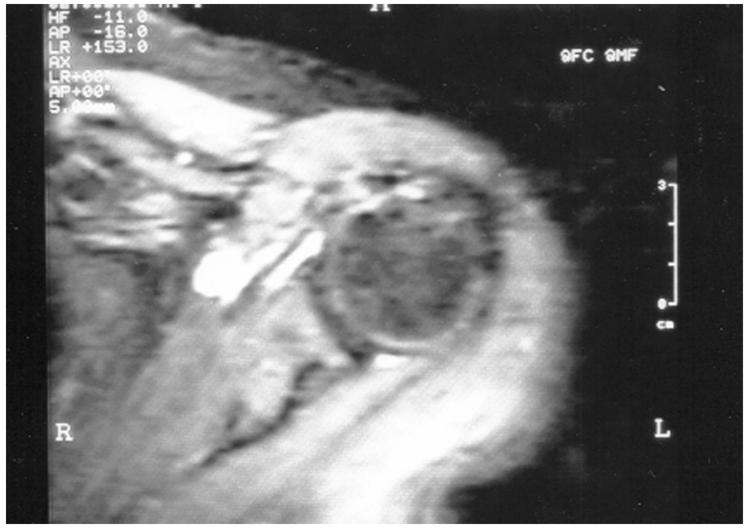

FIGURE 2 *T2-weighted magnetic resonance image of the same patient showing inflammation on the supraspinatus and long head of the biceps tendons (used with written permission of the patient).*

TABLE 3. Predictive values for clinical examination and ultrasonographic findings in the diagnosis of rotator cuff tears and biceps pathologies

	Impingement Test Maneuvers	Cuff Tears on Ultrasonography	Speed's Test for Biceps	Biceps Pathologies on Ultrasonography
Sensitivity	36/46 (78.3%)	52/53 (98.1%)	18/26 (69.2%)	36/36 (100%)
Specificity	6/12 (50%)	3/5 (60%)	6/10 (60%)	23/23 (100%)
PPV	36/42 (85.7%)	52/54 (96.3%)	18/22 (81.8%)	36/36 (100%)
NPV	6/16 (37.5%)	3/4 (75%)	6/14 (42.9%)	23/23 (100%)
Accuracy	42/59 (71.2%)	55/59 (93.2%)	24/59 (40.7%)	59/59 (100%)

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

tus tears in six cases with MRI verification (37.3% *vs.* 27.1%).

DISCUSSION

The final stage of impingement concept of Neer[1] is that the degeneration and rupture of the supraspinatus tendon, often associated with osseous changes, is usually seen in patients >40 yrs of age. Although there were many studies including radiologic and arthroscopic evaluation of this stage, clinical findings and functional evaluation of the shoulder were lacking, despite its importance. This was the first clinical and radiologic study using DASH (disabilities of the arm, shoulder, and hand) as functional scoring in SIS. Strikingly, glenoid labral tear and subacromial effusion/hypertrophy on MRI were the determinants of shoulder disability in our study. Because ultrasonography could not detect glenoid labral tears, MRI should have been selected for disabled and treatment-unresponsive shoulders for suspected superior labrum anterior posterior lesion.

Although it was an uncontrolled study with a relatively small sample size, we found that basic clinical evaluation of the shoulder was well correlated with MRI findings. We suggested that basic clinical examination is, in general, initially sufficient for the patients with SIS because of the 78.3% sensitivity we found. However, advanced imaging modalities should be considered for patients who are unresponsive to the conservative approaches such as physical therapy, Cyriax or manual therapy, specific SIS exercises, and medication for 3 wks. We can consider ultrasonography, with 98.1% sensitivity in such cases having rotator cuff tears. In fact, ultrasonography and MRI have been reported to be highly accurate for the detection of rotator cuff lesions in different studies.[6–14] However, MRI was superior to ultrasonography for the detection of overall pathologies, except for biceps lesions, in our study. Alasaarela et al.[24] found similar results in 31 painful shoulders with chronic arthritis. This may be explained by the superficial localization of the long head of the biceps tendon. There have also been reported poor results of ultrasonography[15–17] for the detection of rotator cuff tears with the use of arthrography or surgery as the gold standard. It would be better if we could have compared our results with arthroscopic findings; however, our patients had not accepted arthroscopic evaluation. Therefore, MRI was used as our gold standard. We did analyze sensitivity and specificity of ultrasonographic and clinical tests, despite our small sample size. Actually, some sensitivity/specificity studies showed no significant differences between ultrasonography and MRI for the detection of rotator cuff diseases.[6,8,10,25] The use of variable high-frequency linear-array transducers instead of a 7.5-MHz or 5-MHz curved-array transducer can increase the accuracy of ultrasonography to detect rotator cuff diseases.[6] Our use of 7.5-MHz linear and 5-MHz curved-array transducers may have been to our disadvantage, as suggested by several studies.[8,10,25] The differences in results may be due to differences in the selection of patients, ultrasonographic techniques, or level of experience of investigators. Neither clinical nor functional evaluation of the shoulder has been reported in any of these studies. It is difficult to understand why clinical information, such as that regarding lesions of the glenoid labrum, joint capsule, surrounding muscles and bones, and functional level of the upper limb, have been ignored. It may depend on surgical or radiologic points of view. However, the functional level of the upper limb is of critical importance in choosing the therapeutic approach and in determining the prognosis of the patient.

The choice of an advanced imaging method can be based on the patient's characteristics, such as age, sex, unresponsiveness to nonsurgical treatment, clinical and radiographic information, hospital characteristics of its radiology department, and cost. Ultrasonography is an operator-dependent technique, an experienced radiologist is needed, and it has limited value for glenoid labrum pathologies.[6] However, ultrasonography does have several potential advantages over MRI, including low cost, portability, dynamic features, possibilities of metallic-implants evaluation, and percutaneously guided procedures.[5] Patients with a metal foreign body near critical organs or with certain ferromagnetic devices or implants cannot undergo MRI. In addition, MRI may not be feasible because of claustrophobia or lack of health insurance or finances. In these situations, ultrasonography should be considered as an alternative to MRI. One great advantage of MRI over ultrasonography is its ability to accurately depict muscle atrophy in shoulders with rotator cuff tears, glenoid labrum, joint capsule, articular cartilage, and surrounding muscles and bone for morphologic changes that may influence the patient's symptoms, treatment, and prognosis.[3]

Shoulder MRI was a better technique than ultrasonography for the detection of glenoid labral tears, bone erosions, and synovial effusions. However, because of cost-effectiveness issues and similar accuracy values with ultrasonography, MRI may be performed in patients considered as mini-open or arthroscopic surgery candidates.

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