

Original Article

The Role of MRI Following Ultrasound in Detection of Rotator Cuff Tears

Rumpa Banerjee¹, Indranil Dutta²

Background : The shoulder joint has a wide range of motion in multiple planes - stability is compromised for mobility. It is an incongruous (large) ball and (small) socket joint without any fixed axis of rotation. Although a number of clinical tests are described for diagnosing painful shoulder, considered accurate in determining the location of periarticular lesions, shoulder pathology may be difficult to diagnose by physical examination alone.

Magnetic Resonance Imaging (MRI) and Ultrasonography have supplanted arthrography in the evaluation of the integrity of the rotator cuff.

Materials and Methods : The data for the study was collected from patients complaining of shoulder pain and restriction of movements, suspected for rotator cuff tears referred for Ultrasonography (USG) examination to the department of Radiodiagnosis, AIIMS, Mandya.

Results : In this study group which comprised of a total number of 50 patients, The most common symptom in patients who presented to the Orthopaedics Department with rotator cuff injuries was shoulder pain and restriction of movements comprising 72% and 28% of cases respectively. Among 50 patients who underwent ultrasound examination, 14 patients were diagnosed as having Full Thickness Tears (FTT) and 30 patients showed Partial Thickness Tears (PTT). In relation supraspinatus tendon, USG detected 34 truly positive supraspinatus tears (14 full & 30 PTT).

Conclusion : Based on our results, it can be concluded that Ultrasonography is an effective imaging modality that has a positive effect on the management of many patients presenting with shoulder pain and/or disability. MRI can be used as second line Diagnostic Tool.

[J Indian Med Assoc 2025; 123(2): 33-9]

Key words : Musculo Skeletal (MSK), Acromio Clavicular Joint (ACJ), Positive Predictive Value (PPV), Negative Predictive Value (NPV), Partial Thickness Tears (PTT), Full Thickness Tears (FTT).

The shoulder joint has a wide range of motion in multiple planes - stability is compromised for mobility. It is an incongruous (large) ball and (small) socket joint without any fixed axis of rotation. The muscles and their tendons are subjected to severe strain causing excessive "wear and tear" during sports and games activities. The spectrum of causative lesions that can give rise to shoulder pain ranges from acute trauma to degenerative disorders as well as impingement syndrome. Although a number of clinical tests are described for diagnosing painful shoulder, considered accurate in determining the location of peri-articular lesions, shoulder pathology may be difficult to diagnose by physical examination alone. Clinical diagnosis has low accuracy in comparison with arthroscopy^{1,2}.

Rotator cuff injury has a distinct range of chronic disorders. These disorders are related to the osseo-

¹MBBS, MD (Radiodiagnosis), Assistant Professor, Department of Radiodiagnosis, Gouri Devi Medical College Hospital & Research Institute, Durgapur, West Bengal 713212 and Corresponding Author

²MBBS, MS, PGDHHM, PGDMLS, Professor and Unit Head, Department of Obstetrics and Gynaecology, IQ City Medical College Hospital, Durgapur, West Bengal 713206

Received on : 11/06/2024

Accepted on : 30/06/2024

Editor's Comment :

- Ultrasonography is an effective imaging modality that has a positive effect on the management of many patients presenting with shoulder pain and/or disability.
- There was a good agreement between USG and MRI in diagnosing rotator cuff pathologies

tendinous and musculotendinous part of the Rotator cuff and the anatomically narrow sub-acromial space. Due to this problem Ultrasound is often recommended as primary Diagnostic Tool. Ultrasound technology has taken leaps and advances in its course over the years and has contributed immensely to help us diagnose cases of rotator cuff pathology. Main advantage lies in the fact that ultrasound is non invasive, easy to perform, less expensive and has good sensitivity in diagnosing both rotator cuff and non rotator cuff disorders³. Another benefit also lies in the fact that it is also a non-ionizing modality.

In spite of above advancements plain film radiography serves as basic and first line in most of cases particularly in rural areas where the above modality is easily available and prescribed for bony trauma and most athropathies. Magnetic Resonance Imaging and Ultrasonography have supplanted arthrography in the evaluation of the integrity of the

rotator cuff⁴. The overall joint structure assessment and detection of both subtle and obvious internal derangement has become easier with MRI being available and is considered as “Gold Standard” in diagnostic modality³. MRI have a advantage because of its multi-planar capability and exquisite soft tissue detail which helps us with detailed diagnosis.

In last 20 years or more Ultrasound technology has been the upfront in field of sports medicine and rheumatology and it has rightfully gained its place in literature along with MRI. The main advantage in USG is its real time capability in conducting dynamic studies in the shoulder as well as the patient’s ability to point out the discomfort caused by particular movement or position.

In this study approximate 50 patients who had shoulder joint pain and restriction of movements with a suspicion of rotator cuff injuries clinically were advised both USG and MRI of the shoulder joint. The main aim of this study was to show that ultrasound technology was as effective as MRI in the evaluation of shoulder pain, especially in cases of rotator cuff injuries.

MATERIALS AND METHODS

Source of Data : The data for the study was collected from patients complaining of shoulder pain and restriction of movements, suspected for rotator cuff tears referred for Ultrasonography (USG) examination to the Department of Radiodiagnosis, Sri Adichunchanagiri Hospital and Research Centre, B G Nagara, Nagamangala Taluk, Mandya District.

Study Design : Descriptive study.

Study area : Sri Adichunchanagiri Hospital and Research Centre, B G Nagara.

Study period : January, 2016 to August, 2017

Sample Size : 50

Statistical analysis : The agreement between the two methods was assessed using kappa coefficient.

Inclusion Criteria :

- All patients in any age group.
- All patients with shoulder pain, restriction of movements of shoulder and suspected rotator cuff injuries.

Exclusion criteria :

- Other trauma/ open wounds.
- Malignant and infectious conditions.
- Patient having a history of claustrophobia.
- Patient having a history of metallic implant or cardiac pacemaker insertion or any metallic foreign body embedded in the tissues.

Equipment :

- USG – GE Voluson S6 Pro with linear probe of frequency range 7-12 MHz.
- MRI – Siemens 1.5 Tesla MRI superconducting magnet.

Scanning Technique for USG :

The patient is seated opposite to examiner in a high revolving chair; the probe which is used is a high frequency linear type, a broadband probe like L5-12 is ideal. The basic principles of MSK USG is that it is necessary to follow the curve of the bone, identify useful bony landmarks like the acromion process, biceps tendon, and the labrum^{4,5}. Each structure has to be examined in 2 planes and maintaining perpendicularity to tendon fibers, should be followed.

Following sequence when examining the shoulder joint to followed —

- Biceps tendon
- Subscapularis
- Supraspinatus (including test for impingement)
- Infraspinatus
- Teres minor
- Posterior glenoid labrum and glenohumeral space
- Coraco-acromial ligament
- The Acromioclavicular joint.

Criteria for Diagnosis of Rotator Cuff Tear :

Various criteria’s have been defined over the years for rotator cuff tears. The criteria devised and suggested by Middleton are easy to follow and report^{6,7}. One should always examine the integrity, thickness and echogenicity of the cuff and look out for calcification. The size of the tear, its orientation, and its location relative to the biceps tendon has to be reported.

Major Criteria :

(1) Non-visualization of the Cuff (Fig 1) : If the cuff is not visualized totally then it may suggest a complete tear. But the problem lies in the fact that a novice person can easily miss this finding since the entire supraspinatus tendon is missing and the deltoid with the subdeltoid bursa then rests on the head of the humerus. The best way to confirm this is by comparing with the other side. An important indirect clue in this situation is the loss of the normal convexity of the deltoid and bursa with dipping of the same (with concavity) in the empty space. This is the most important indirect sign. Bursal thickness and fluid in the subdeltoid bursa and along the biceps are very commonly associated. The hyaline cartilage on the humeral head stands out. This often referred to as the naked tuberosity or double arc sign.

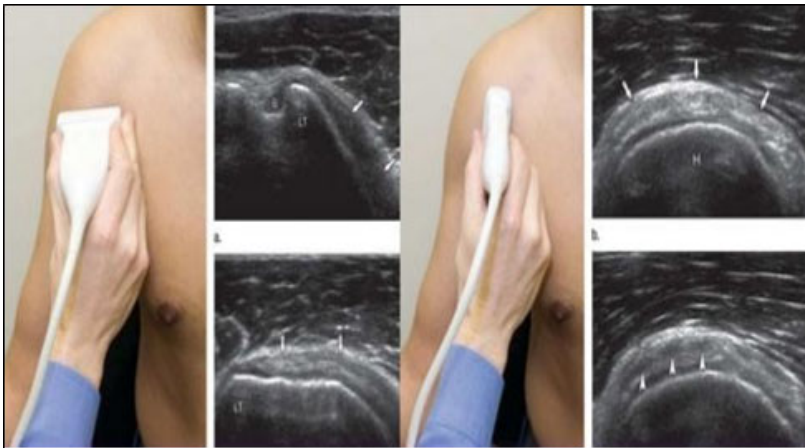


Fig 1 — Subscapularis tendon

(2) Focal non-visualization : Focal non-visualization of the tendon is relatively easy to diagnose, as the remaining tendon is seen adjacent to it. Within this gap, the subdeltoid bursa can also dip. Confirmation in two planes is important. Most rotator cuff pathologies occur in the terminal 1 cm of the tendon, which is the critical zone.

(3) Discontinuity : Discontinuity of fibers may be seen, the gap filled with fluid or reactive tissue. A stress test, by positioning the elbow with the arm internally rotated, is the best way to check for discontinuity of the fibers. It is also apparent by the compressibility of the tendon compared to a normal tendon, which is non compressible. (The subscapularis tendon is best examined while performing passive external rotation and internal rotation. In external rotation the tendon becomes more prominent, as it is medial to the biceps tendon. It must be examined in two planes. Injuries of the subscapularis are rare, except in the event of direct trauma)

(4) Focal abnormal Echogenicity : Full or Partial Thickness Tears (PTT) is usually associated with this. The area of increased echogenicity is thought to result from granulation tissue, hypertrophied synovium, and hemorrhage. The radiologist should be able to confirm this is real and not an artifact or rotator cuff calcification.

Minor Criteria for Rotator Cuff Tear :

(1) Reliable sign of rotator cuff injury can be elicited by presence of fluid along the biceps tendon sheath and in subdeltoid bursa and the joint. Fluid along the biceps tendon sheath and in the subdeltoid bursa and the joint is a very reliable sign of rotator cuff injury. Cuff tear can be suspected by presence of fluid along the biceps tendon and in the joint^{7,8}.

(2) Concave subdeltoid bursal contour.

(3) Irregularity of the greater tuberosity⁹.

(4) Compressibility.

Partial-thickness Tears :

For the evidence of PTT, Middleton's group uses either a distinct hypoechoic or mixed hyper and hypoechoic defect visualized in two planes at the deep articular side of the cuff, or minimal flattening of the bursal side of the cuff. When tears involve bursal surface, intra substance or articular surface tears then they fall under definition of

partial tears. Around 80% of accuracy has been noted in the diagnosis of PTT⁸.

Some of the reports suggests that USG is a significantly better modality for the evaluation of partial-thickness tears than MRI.

Imaging Technique for MRI :

Imaging Parameters					
Sequence	FOV(cm)	Slice Thickness	Interval	TR	TE
Coronal PDFS	16	4mm	0.5mm	1850	32
Axial T2	16	4mm	0.5mm	5367	97
Coronal T2	16	4mm	0.5mm	2700	90
Axial PDFS	16	4mm	0.5mm	1967	26
Sagittal T1	16	4mm	0.5mm	110	12
Sagittal PDFS	16	4mm	0.5mm	2400	35

ANALYSIS AND RESULTS

Age Distribution of Patients in the Study :

In this study group which comprised of a total number of 50 patients, the age at presentation ranged from 25 to 65 years. Most patients belonged to the 36-45 years and 46-55years age groups with 16 and 19 patients respectively. There were 51 Males and 9 Females in the patients included in the study group. Males comprised 86% and Females comprised 14% of the group.

Symptoms :

Most of the patients who had presented to Orthopaedics Department with rotator cuff injuries had shoulder pain and restriction of movements comprising 72 % and 28% of cases respectively.

Etiology and Predisposing Factor :

History of trauma was observed in the 38 patients. Among 50 patients Diabetes Mellitus was seen in 20 patients presenting to the Department with shoulder

pain or restriction of movements.

Rotator Cuff Tears in Relation to Dominant Hand :

Out of 32 patients who were right handed, 28 patients had rotator cuff tear involving the right shoulder, 2 had rotator cuff tear involving the left shoulder and 2 patients had no tear. In 12 patients had rotator cuff tear involving the left shoulder out of 18 patients who were left handed. Four had rotator cuff tear involving the right shoulder and 2 patients had no tear. It suggests that dominant arm is more susceptible to wearing effects and thus leads to rotator cuff tear.

Supraspinatus Tear :

Fourteen patients were diagnosed as having full thickness tears and 30 patients showed Partial Thickness Tears (PTT) among 50 patients who underwent ultrasound examination. 14 patients had articular surface PTT and 16 patients were found to have bursal surface PTT. On MRI 14 patients showed full thickness tears and 32 patients showed PTT. Fifteen patients were diagnosed with articular surface PTT and 17 patients with bursal surface PTT on MRI. Seven patients had tendnosis and impingement which was detected both on USG and MRI. Both USG and MRI had good diagnostic capability for rotator cuff tears (Table 1).

Table 1 — Agreement between USG and MRI for the diagnosis of Supraspinatus Tears

MRI						
	FTT	PTT	Tendinosis	Impingement	No tear	Total
FTT	14	2	0	0	0	16
PTT	0	30	0	0	0	30
USG						
Tendinosis	0	0	7	0	0	7
Impingement	0	0	0	7	0	7
No tear	0	0	0	0	4	4
Total	14	32	7	7	4	64

Kappa= 0.954, SE of kappa = 0.032, 95% confidence interval: From 0.891 to 1.000

Table 2 — Agreement between USG and MRI for the diagnosis of subscapularis tears

MRI					
	FTT	PTT	Tendinosis	No tear	Total
FTT	3	1	0	0	4
PTT	0	6	0	0	6
USG					
Tendinosis	0	0	4	0	4
No tear	0	0	0	4	4
Total	3	7	4	4	18

Kappa= 0.615, SE of kappa = 0.117, 95% confidence interval: From 0.386 to 0.843.

Subscapularis Tear :

Among 50 patients who underwent ultrasound examination, 3 patients were diagnosed as having Full Thickness Tears (FTT) and 6 patients showed PTT. On MRI 3 patients showed full thickness tears and 7 patients showed partial thickness tear. 4 patients had tendnosis which was detected both on USG and MRI. USG findings showed good correlation with MRI findings (Table 2).

Infraspinatus Tears :

Among 50 patients who underwent Ultrasound examination, 2 patients were diagnosed as having PTT on USG. On MRI 3 patients showed PTT. FTT of the tears of the Infraspinatus were not detected both on USG and MRI. USG findings showed good correlation with MRI findings (Table 3).

Teres Minor Tears :

Two patients had partial thickness tear of teres minor on USG. However on MRI, 3 patients showed partial thickness tears of the teres minor. Full thickness tears of the tears of the Infraspinatus were not detected both on USG and MRI. USG findings showed good correlation with MRI findings (Table 4).

Sensitivity and Specificity Analysis of USG in Relation to Rotator Cuff Tears with respect to findings in MRI :

In relation supraspinatus tendon, USG detected 34 truly positive supraspinatus tears (14 full & 30 PTT)

Table 3 — Agreement between USG and MRI for the diagnosis of Infraspinatus Tears

MRI				
	FTT	PTT	No tear	Total
FTT	0	1	0	1
PTT	0	2	0	2
USG				
No tear	0	0	4	4
Total	0	3	4	7

Kappa= 0.741, SE of kappa = 0.198, 95% confidence interval: From 0.352 to 1.000

Table 4 — Agreement between USG and MRI for the diagnosis of teres minor tears

MRI				
	FTT	PTT	No tear	Total
FTT	0	1	0	1
PTT	0	2	0	2
USG				
No tear	0	0	4	4
Total	0	3	4	7

Kappa= 0.741, SE of kappa = 0.198, 95% confidence interval: From 0.352 to 1.000

2 falsely negative as normal while 4 patients were diagnosed as normal (True negative). No false positive cases were noted. The sensitivity, specificity and accuracy of USG against the MRI for Full thickness finding are 100%, 100% and 100% respectively. The sensitivity, specificity and accuracy of USG against the MRI for Partial thickness finding are 93.75%, 100% and 94.4% respectively. In relation subscapularis tendon, USG detected 8 truly positive supraspinatus tears (3 full & 6 PTT) 1 falsely negative as normal while 4 patients were diagnosed as normal (True negative). No false positive cases were noted. The sensitivity, specificity and accuracy of USG against the MRI for Full thickness finding are 100%, 100% and 100% respectively. The sensitivity, specificity and accuracy of USG against the MRI for Partial thickness finding are 85.7%, 100% and 90.9% respectively.

In relation infraspinatus and teres minor tendons, USG detected 1 truly positive infraspinatus and teres minor PTT, 1 falsely negative as normal for both muscles, while 4 patients were diagnosed as normal (True negative). No false positive cases were noted. The sensitivity, specificity and accuracy of USG against the MRI for PTT of infraspinatus and teres minor tendon are 50%, 100% and 83.3% respectively. Sensitivity, specificity of USG could not be assessed as FTT of infraspinatus muscle was not found even on MRI.

The overall sensitivity, specificity, PPV and NPV of Ultrasound compared to MRI in detection of full thickness rotator cuff tear was 100% in each category respectively. The overall sensitivity, specificity, PPV and NPV of ultrasound compared to MRI, for detection of rotator cuff tear was 84.4%, 100%, 100% and 36% respectively. The accuracy of ultrasound compared to MRI in diagnosis of FTT and PTT was 100% and 85.7% respectively.

Acromio-clavicular (AC) Joint Arthrosis and Impingement :

Among 46 patients with rotator cuff tear, AC joint arthrosis was seen in 25 on USG examination. On MRI 29 patients were diagnosed with AC joint arthrosis. On dynamic USG examination impingement of supraspinatus tendon was seen in 7 patients. However in MRI impingement was observed in only 4 patients.

DISCUSSION

Patients who present with rotator cuff injuries usually present to OPD with shoulder pain and restriction of movements and account for 30 to 70

percent of these cases^{10,11}. The integrity of rotator cuff has to be attained along with extent of tear while assessing these patients. Thus it will help the surgeons to plan up the cases. Arthrography has been used for the diagnosis of rotator cuff tears^{12,13}.

Ultrasonography of the shoulder was first reported by Seltzer, *et al*⁴. Since then several authors have been discussing and refining this method^{15,16}. There are several advantages of USG over MRI. Because Ultrasonography has been more dynamic form of imaging compared to MRI, it has been preferred widely for the diagnosis. Main advantage lies in USG is its portability, quick, and a more cost-effective method. Thus it enables USG to be well accepted by patients and also enables patient to point out the main area of trauma or pain to have a better visualization and thus helping in the diagnosis. Portable USG Scanners though difficult to acquire in our country, the advent of portable USG scanners has made it easier for Orthopaedicians to help acquire the knowledge and skill and also perform USG in the clinic at the first point of contact. This actually helps reduce the burden from the Radiology Department and also saves enormous amount of energy, time and money.

Al-shawi, *et al*¹⁷ have reported a sensitivity and specificity of 96.2% and 95.4%, respectively in 143 consecutive patients with shoulder problems, who underwent shoulder USG by an Orthopedic Surgeon, and Joseph, *et al*¹⁸ reported the use of office-based ultrasonography by an Orthopedic Surgeon with 88% accuracy for full-thickness and 70% for PTT.

The ages of all the cases ranged from 25 to 65 years. Out of these 50 patients; 6(12%) patients were in 25-35 years age group, 16(32%) were in 36-45 years age group, 19(38%) in the were in the 46-55 years age group while 9(18%) patients were in 56-65 years age group. Hence, outcome was an increase in the prevalence of shoulder pain and rotator cuff tears with advancing age. Another study by Jerosch, *et al*¹⁹ suggested similar findings in their study.

Yamamoto A²⁰, *et al* had reported in their study that rotator cuff tears were commonly associated with male populations²⁰. Our M:F Ratio was 4.5:1 (Out of 50 patients, 41 were males (82%) and 9 (18%) were females) which was comparable to above study by Yamamoto A²⁰, *et al*.

Out of 32 patients who were right handed, 28 patients had RCT involving the right shoulder and 2 had RCT involving the left shoulder. Out of 18 patients who were left handed, 12 patients had RCT involving the left shoulder and 4 had RCT involving the right

shoulder. It suggests that dominant arm is more susceptible to wearing effects and thus leads to RCT. The findings of above suggested that right shoulder was more involved than left shoulder. As suggested by Bouaziz²¹, *et al* who suggested right shoulder involvement (68%) more than left shoulder involvement (32%)²¹ and is hence comparable to above.

Diabetes was seen in approx 45% of patients and was noted as one of significant predisposing factors pushing rotator tendons to tears. Trauma was identified as the major etiological factor, present in 86.6% of RCT. Contralateral shoulder was also checked via USG for comparison. It was Rutten, *et al*²² who recommended comparison with the contralateral shoulder as an additional support for avoiding misinterpretation of normal anatomic differences as tears²².

Among 50 patients, tears involving the supraspinatus tendon were more common seen in 92% of patients. Subscapularis was next most commonly involved tendon seen in 20% of the patients. Infraspinatus and teres minor was seen 4% of the patients respectively. Similar findings were seen in the study conducted by Bashir, *et al*²³.

On USG out of 44 patients, 30 patients had PTT, 14 had FTT. When MRI was conducted in these patients, it showed 14 FTT and 32 PTT, which means that 2 patients were falsely diagnosed as normal on USG that turned out to be PTT on MRI. Both methods of MRI and USG were assessed and compared using Kappa Co-efficient. There was a very good agreement ($k=0.954$) between USG and MRI. Out of 50 patients, 9 patients were diagnosed with subscapularis tears of whom 3 patients had full-thickness tears and 6 patients had PTT on USG.

One patient was falsely diagnosed as normal on USG which was found to be PTT on MRI. MRI was conducted in these patients, it showed 3 full-thickness tears and 7 PTT. Similar results were obtained by Alasaarela, *et al*²⁴ and Rutten²². Evaluation of 31 painful shoulders of 30 patients and reporting a good agreement between US and MRI for diagnosis of FTT and intra-substance abnormalities of supraspinatus tendon (the kappa co-efficient =0.73) by Alasaarela, *et al*²⁴. In 68 patients who underwent MRI and surgery following USG examination and reported that agreement between US and MRI was high (the kappa coefficient was calculated to be 0.78) in the study conducted by Rutten, *et al*²².

Our study showed sensitivity, specificity, PPV and NPV of 100% respectively for high resolution USG

when compared to MRI for full thickness. The accuracy of USG in diagnosing a FTT is 100% and 85.7% for partial thickness tears. The current study also showed similarity to studies conducted by Kenn, *et al*⁸ and Lach, *et al*²⁹ and proved that ultrasound is accurate in diagnosing rotator cuff pathologies. Ultrasound was as accurate as MRI for assessment of tears of the rotator cuff, both full- or partial-thickness tears according to Saraya, *et al*²⁵. In our study USG showed ACJ arthrosis in 25 patients (86.2%) in comparison to 29 patients (93.5%) on MRI, proving that though USG is easily available, it's still less accurate compared to MRI for ACJ evaluation.

MRI detected supraspinatus impingement in only 4 patients. USG was more accurate than MRI in detecting supraspinatus impingement. The findings in our study were comparable with the study conducted by Nathalie J, *et al*⁶. The advantage lies in the fact that MR imaging can quantify the degree of muscle atrophy by assessing the occupancy ratio of the supraspinatus muscle in the supraspinatus fossa²⁷. Oblique sagittal T1W view in MRI best depicts chronicity of a rotator cuff injury

CONCLUSION

So the above wide comparative study noted results suggesting that USG is an effective imaging modality that has a positive effect on the management of many patients presenting with shoulder pain or disability. Ultrasound of shoulder has a good accuracy in diagnosing tears of the rotator cuff and in differentiating partial from full-thickness tears. Also important to note that there was good agreement (kappa value=0.79) between USG and MRI in diagnosing rotator cuff pathologies.

From the study there were notable advantages noted in USG over MRI such as USG is available on a larger scale, portable, quick and a much more cost-effective imaging method. Most importantly is well tolerated by patient because they can point out the main area which is affected to the Radiologist thus helping in accurate diagnosis.

Ultrasound allows instant comparison to contralateral side and it helps in dynamic evaluation of the same. However, sonography of the shoulder joint is operator dependent. Hence small transducer related errors and angulation can easily obscure small abnormalities within and around the cuff and give rise to false positive and false negative results. The learning curve is also difficult for shoulder Sonography. If the observer has good knowledge about the anatomy of shoulder then above problem of diagnosing with USG can be easier. Sonography

is an effective, reliable and noninvasive means of detecting rotator cuff tears.

Hence, both USG and MRI are considered as comparable modalities for diagnosis, USG can be used for first line investigation whereas MRI can be used as second line tool, either following an equivocal shoulder USG or for delineation of anatomy in cases where surgical correction is needed.

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