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Original Research Article

Diagnostic Accuracy of Ultrasound for Rotator Cuff Tears of Shoulder Joint Compared to Magnetic Resonance Imaging

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Abstract:

Introduction: Rotator cuff pathologies are a common cause of shoulder pain and disability. Ultrasound and MRI are preferred for diagnosing rotator cuff tears, with MRI offering high sensitivity and specificity but being costly and time-consuming. Ultrasound is a cost-effective alternative, but its accuracy in distinguishing complete and partial tears can vary. This study aimed to compare the accuracy of US and MRI in diagnosing rotator cuff pathologies.

Materials and Methods: This prospective study enrolled 40 patients who were referred for ultrasound and MRI due to shoulder pain. Radiologists performing the ultrasound and reporting the MRI results were unaware of each other's findings. The study aimed to determine the sensitivity, specificity, and accuracy of ultrasound in diagnosing different musculo-tendinous shoulder pathologies, using MRI as the gold standard.

Results: Patients with rotator cuff tears had a mean age of 48.5 ± 10.2 years. Both ultrasound and MRI showed strong agreement (k = 0.80) in diagnosing rotator cuff tears. The supraspinatus tendon (65.4%) was most commonly affected. Ultrasound had high accuracy in diagnosing supraspinatus tears (98.0%), followed by infraspinatus (94.0%) and subscapularis (90.0%). Accuracy was better for larger full-thickness tears (100%) compared to partial thickness tears (85.0) and tendinosis (87.5%).

Conclusion: Ultrasound and MRI have good agreement in diagnosing rotator cuff pathologies. Ultrasound is the preferred choice due to its availability, affordability, and tolerability, with MRI reserved for uncertain ultrasound results.

Keywords: Accuracy, agreement, magnetic resonance imaging, rotator cuff tear, supraspinatus, ultrasound

Introduction

Rotator cuff pathologies (RCP), particularly rotator cuff tears 9RCT), are a common cause of shoulder pain and disability. [1] The rotator cuff muscles comprise supraspinatus, infraspinatus, subscapularis, and teres minor. The rotator cuff tendons can be affected by impingement and tendinopathy, which can lead to tears. Rotator cuff problems can be caused by both external and internal factors, such as microtrauma and tendon degeneration. These issues can lead to tears and severe shoulder joint dysfunction, making daily activities difficult. [2]

Clinical examination alone is limited in determining the best treatment for a rotator cuff tear. The decision depends on an accurate diagnosis and the severity of the tear. [1] High-resolution ultrasound (USG) and magnetic resonance imaging (MRI) are the preferred imaging modalities for evaluating rotator cuff tears. Accuracy, availability, cost effectiveness and expertise are some of the important parameters that guide the process of making a decision on the best modality. [3]

Magnetic Resonance Imaging (MRI) is non-invasive and has high sensitivity and specificity, but it can be costly and time-consuming. It has a high spatial resolution for examining soft tissue, such as tendon swelling and muscle cuff rips. On the other hand, Ultrasound (USG) is a cost-effective and widely accessible alternative that provides dynamic real-time examination. However, its accuracy in distinguishing between complete and partial tears can vary, as it relies on the operator's expertise.[1] The

results of the USG and MR examinations were nearly comparable. [4] There have been studies comparing the accuracy of ultrasound and MRI, but more research is needed. This study aimed to compare the accuracy of USG and MRI in diagnosing rotator cuff pathologies.

Material and methods

In this study, 40 patients aged 18-75 were included who were referred to the radiology department for ultrasound and MRI to evaluate suspected rotator-cuff pathology. Clinical examination and shoulder radiography were also performed. Study was conducted after approval from institutional ethics committee and informed consent was taken from all patients.

All patients clinically suspected of Rotator cuff pathology were included. Patients with metallic implants, prosthesis or pacemaker, claustrophobia, bio stimulators, neurostimulators, cochlear implants, prior shoulder surgery, fracture/dislocation, suspected tumor/malignancy, or those who refused to consent were excluded.

Shoulder MRI

The MRI scans were performed using a GE Optima MR 360 (1.5 Tesla) machine. Standard techniques were used, including various sequences like coronal oblique T1W/PD W fast-spin echo, coronal oblique fat-suppressed PDW/T2W FSE, sagittal oblique T2W FSE, axial T2W gradient-echo, and axial PDW fast spin-echo. MRI findings were classified into intact cuff, partial-thickness tear (PTT) and full-thickness tear (FTT), and tendinopathy. MRI findings were taken as gold standard for this study.

The MRI criteria for rotator cuff pathology are as follows: [5,6]

- Tendinopathy is defined as increased signal intensity on Proton Density (PD) Weighted images, but not as bright as fluid signal on T2 Weighted sequence.
- PTT is defined as focal increased signal intensity or discontinuity of fibers on T1 Weighted, PD Weighted, and T2 Weighted sequences, which is as bright as fluid signal on T2 Weighted sequence. It can involve the bursal or articular surface or mid substance of the tendon.
- FTT is considered when the focal discontinuity involves the full thickness of the tendon from the bursal surface to the articular surface, with retraction of the torn ends. The gap is either filled with fluid signal intensity or altered signal intensity of granulation tissue.

Shoulder Ultrasound

The ultrasound examinations were done using the VOLUSON E8 EXPERT BT09 (GE) machine with a wide-band linear transducer. The radiologists performing the ultrasound and reporting the MRI scans were not aware of each other's findings. The patient was asked to sit at on a revolving stool while the examiner used a similar stool. The scanning protocol included evaluating various tendons and joints. [7] It was ensuring that the ultrasound beam was perpendicular to the tendon, and assessing for impingement through dynamic abduction. The examination also involved comparing the affected side with the contralateral side and evaluating other joint abnormalities.

Ultrasound criteria for rotator cuff pathology[7]

- Tendinosis/Tendinopathy: Characterized by a tendon that appear thickened with loss of normal hyperechoic fibrillar pattern. There may be a heterogeneous, ill defined, hypoechoic area in the tendon with variable change in the caliber (enlarged / thinned) without a tendon defect.
- Rotator Cuff Tear:
  - PTT: A well-defined focal hypoechoic or anechoic abnormality that disrupt the tendon fibers which is limited to either articular surface or the bursal surface of the tendon, or intra muscle substance, but without communication of the tear to the opposing tendon surface. PTT was classified into “articular side” tear or “bursal side” tear and “high-grade” (greater than 50% thickness) or “low-grade” (less than 50% thickness) tear.
  - FTT: Characterized by a defect, a hypoechoic zone, that disrupts the hyperechoic tendon fibers and extend through the entire substance of the rotator cuff muscle (s) from the articular to bursal surface of the tendon. There may non - visualization of the tendon, hypoechoic discontinuity of the tendon, or retracted edge of the torn tendon. The full thickness tears were classified into small (<1 cm), medium (1-3 cm), large (3-5 cm) and massive (>5 cm), measured in its longest dimension.

Statistical Analysis

The collected data was analyzed using EPI Info software. Quantitative data was described as mean ± SD, and qualitative data was described as frequency and percentage. The significance of the difference between qualitative data was examined using the chi-square test. A p-value of less than 0.05 was considered significant. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the ultrasound were measured against MRI for diagnosing various rotator cuff pathologies. The strength of agreement between ultrasound and MRI was evaluated using the Cohen kappa coefficient. Kappa values ranging from 0 to 1 were used to assess the level of agreement.

Results

A total of 40 patients with rotator cuff pathology (RCP) were enrolled in the study. Mean age of the patients was 48.5 ± 10.2 years. The majority of patients belonged to the age group between 51 and 60 years (5, 32.5%). Total 24 (60.0%) were males. All patients had unilateral affection of the shoulder. The right shoulder was involved in 28 (70.0%) patients. The most common finding associated with rotator cuff tear was tendinitis (15, 37.5%) followed by acromio-clavicular joint degeneration (5, 12.5%) and glenoid labral tears (7.5%). The most common complaint was pain alone (18, 45.0%) followed by stiffness of joint (8, 20.0%), a combination of pain and stiffness (7, 17.5%), difficulty in raising the arm (6, 15.0%), and weakness (1, 2.5%).

Table 1: Characteristics of patients with rotator cuff pathologies

Characteristics	No of patients	Percentage (%)
Age group		
< 20	2	5
21 to 30	1	2.5
31 to 40	7	17.5
41 to 50	11	27.5
51 to 60	13	32.5
> 60	6	14.5
Mean ± SD	48.5 ± 10.2	
Gender		
Male	24	60.0
Female	16	40.0
Shoulder		
Right	28	70.0
Left	12	30.0
Associated findings		
Tendinitis	15	37.5
Glenoid labral injuries	5	12.5
Acromio-clavicular joint degeneration	3	7.5
Symptoms		
Pain alone	18	45.0
Stiffness of joint	8	20.0
Combination of pain and stiffness	7	17.5
Difficulty in raising the arm	6	15.0
Weakness	1	2.5

Rotator cuff pathology detected by MRI & USG

In the MRI scans, 55 cases of RCP were diagnosed in 40 patients. On the other hand, USG identified RCP in 47 RCP (85.4% - 47/55) in 36 (90% - 36/40) patients. USG was able to diagnose all cases of FTTs, 88.0 % cases of PTTs (22/25) and 95.0% cases of tendinosis (19/20) of rotator cuff, 50% cases of muscle atrophy of teres minor (1/2). In the USG examination, except for one case of full-thickness tear measuring 4 cm in length, all FTTs were moderate in size (2-3 cm). Similarly, except for one case of PTT involving more than 50% thickness of the tendon, all PTTs were classified as low grade.

Table 2: Any pathology in Rotator Cuff Tendons

Pathology	MRI	USG (%)	Missed in USG (%)
Any pathology in Rotator Cuff Tendons	55 abnormalities in 40 patients	47 (85.4%) abnormalities in 36 (90%)	Missed 8 (14.6%) abnormalities in 4 (10%)
Rotator cuff Tendinosis	20	19 (95%)	1 (5%)
Rotator cuff Tear (RCT)	30	27 (90%)	3 (10%)
Partial thickness Tear	25	22 (88.0%)	3 (12.0%)
Full Thickness Tear	5	5 (100%)	0 (0%)
Muscle atrophy	2	1 (50%)	1 (50%)

The USG showed a sensitivity of 89.5%, specificity of 85.7% for detecting tendinosis compared to MRI, with an overall accuracy of 87.5%. For detecting partial-thickness tears (PTTs), the sensitivity, specificity, and accuracy of USG compared to MRI were 95.5%, 72.2%, and 85.0% respectively. And when it comes to full-thickness tears (FTTs), USG had a sensitivity, specificity, and accuracy of 100% each compared to MRI. The agreement between USG and MRI was perfect (k=1.0) for detecting FTTs and substantial for identifying PTTs (k=0.69) and tendinosis (k=0.75).

Table 3: Sensitivity, Specificity, NPV, PPV, and Accuracy of Ultrasound in Detecting Various Rotator Cuff Pathologies Compared to MRI

Pathology	Sn	Sp	PPV	NPV	Accuracy	Kappa Coefficient
Tendinosis	89.5	85.7	85.0	90.0	87.5	0.75
RCT	96.0	80.0	88.5	96.0	96.5	0.80
(i) Partial thickness Tear	95.5	72.2	80.8	92.9	85.0	0.69
(ii) Full Thickness Tear	100	100	100	100	100	1.00
Any pathology	91.7	70.0	82.5	90.5	87.0	0.75

Tendon wise rotator cuff pathology detected by MRI & USG

As evident from Table 4, MRI revealed abnormalities in the supraspinatus tendon (SST) in 36 patients, subscapularis tendon (SubT) pathologies in 12 patients, infraspinatus tendons (IST) in 3 patients, and TM pathology in 2 patients. USG detected abnormalities in the SST tendon in 33 patients (92.0% - 33/36), SubT pathologies in 10 patients (83.0% - 10/12), IST tendons in 3 patients (100% - 3/3), and TM in 1 patient (50.0% - 1/2).

All patients with full-thickness tears (FTTs) of the supraspinatus tendon identified by MRI were correctly diagnosed by USG. However, USG missed partial-thickness tears (PTTs) of the supraspinatus tendon in 5 patients (23.8%) and falsely diagnosed tendinosis in 2 patients.

In the subscapularis tendon, USG missed 3 cases of rotator cuff tendinosis (37.5%) and falsely diagnosed 1 case of PTT. In the infraspinatus tendon, USG correctly diagnosed all cases of rotator cuff tendinosis, FTT, and PTT. Out of 2 cases of muscle atrophy in the TM identified by MRI, USG correctly diagnosed 1 case and missed 1 case.

Table 4: Tendon wise abnormalities of rotator cuff detected by MRI and US.

Pathology	MRI	USG (%%)	Missed in USG (%)
Supraspinatus (SST)	**36**	33 (92%)	3 (8.3%)
Tendinosis	11	13 (11 correctly diagnosed and 2 falsely diagnosed)	0 (0%)
PTT	21	16 (76%)	5 (23.8%)
FTT	4	4 (100%)	0 (0%)
Subcapularis (SubT)	**12**	**10 (83.3%)**	**2 (16.7%)**
Tendinosis	8	5 (63%)	3 (37.5%)
PTT	4	5 (4 correctly diagnosed and 1 falsely diagnosed)	
FTT	0	0 (0.0%)	
Infraspinatus (IST)	**3**	**3 (100%)**	**0 (0%)**
Tendinosis	1	1 (100%)	0 (0%)
PTT	1	1 (100%)	0 (0%)
FTT	1	1 (100%)	0 (0%)
Teres minor			
Muscle atrophy	2	1 (50%)	1 (50%)

As presented in Table 5, MRI found polytendon abnormalities in 10 patients (25.0%), while USG detected abnormalities in more than one rotator cuff tendon in 6 patients (15.0%). Among those with polytendon abnormalities, the most common association was an abnormality in the supraspinatus tendon (SST) with a pathology in the subscapularis tendon (SubT).

Table 5: Distribution of Abnormalities by Number of Rotator Cuff Tendons Involved.

Rotator cuff pathologies	MRI	USG
Abnormality of Supraspinatus tendon alone	27 (67.5%)	27 (67.5%)
Abnormality of Subcapsularis tendon alone	1 (0.3%)	1 (0.3%)
Abnormality of Infraspinatus tendon alone	2 (0.5%)	2 (0.5%)
Pathology of more than 1 rotator cuff tendon	10 (25.0%)	6 (15.0%)
FTT of SST with subcapsularis tendonitis	3	0 (Missed 3 cases)
PTT of SST with subcapsularis tendonitis	4	4
PTT of SST with infraspinatus and subcapsularis tendonitis and fatty muscle atrophy teres minor	1	0 (fatty muscle atrophy teres minor)
PTT of Sub T with SST tendinosis	2	2

Table 6: Sensitivity, Specificity, NPV, PPV, and Accuracy of Ultrasound in Detecting Various Rotator Cuff Pathologies Compared to MRI

Pathology	Sn	Sp	PPV	NPV	Accuracy	Kappa Coefficient
Tendinosis	89.5	85.7	85.0	90.0	87.5	0.75
RCT	96.0	80.0	88.5	96.0	96.5	0.80
(i) Partial thickness Tear	95.5	72.2	80.8	92.9	85.0	0.69
(ii) Full Thickness Tear	100	100.0	100.0	100.0	100.0	1.00
Supraspinatus (SST)						
Tendinosis	100.0	92.0	80.5	100.0	96.0	0.88
RCT	90.6	92.0	100	98.5	98.0	0.80
(i) Partial thickness Tear	85.5	88.5	100.0	98.0	90.5	0.78
(ii) Full Thickness Tear	100.0	100.0	100.0	100.0	100.0	1.00
Subcapsularis (SubT)						
Tendinosis	70.0	92.0	95.0	96.0	90.0	0.70
RCT	100.0	90.5	85.6	98.5	92.5	0.75
(i) Partial thickness Tear	100.0	88.0	70.0	98.0	90.0	0.68
(ii) Full Thickness Tear	100.0	100.0	100.0	100.0	100.0	1.00
Infraspinatus (IST)						
Tendinosis	100.0	100.0	100.0	100.0	100.0	1.00
RCT	68.2	100	100	98.3	94.0	0.78
(i) Partial thickness Tear	55.8	100.0	100.0	96.0	90.5	0.70
(ii) Full Thickness Tear	100.0	100.0	100.0	100.0	100.0	1.00

The results comparing USG to MRI for diagnosing different types of rotator cuff tendon pathologies are summarized in Table 6.

- SST: USG had a perfect agreement with MRI in detecting FTT (k=1.0), almost perfect agreement for diagnosing tendinosis (k=0.88), and substantial agreement for diagnosing PTT (k=0.78)
- SubT: USG had a perfect agreement with MRI in detecting FTT (k=1.0), substantial agreement for diagnosing tendinosis (k=0.70) and PTT (k=0.68).
- IST: USG had a perfect agreement with MRI in detecting FTT and tendinosis (k=1.0 for each), and substantial agreement for diagnosing PTT (k=0.70). However, US had low sensitivity in detecting PTT of the IST.

Discussion

Rotator cuff tears are common in patients with shoulder pain. Both ultrasonography (USG) and MRI are non-invasive imaging options to evaluate these tears, and USG can be used as a primary modality with comparable accuracy to MRI, as mentioned in the literature.[1]

Characteristics of patients

Age distribution: In the present study, patients with rotator cuff tears had a mean age of 48.5 ± 10.2 years, with the highest occurrence in the fifth and sixth decades of life. This age distribution is consistent with findings from Koganti et al. [2] and Singh et al.1 Additionally, studies by Ozaki et al. [8] suggest that the pathogenesis of rotator cuff diseases is an intrinsic process, with decreased vascularity in the cuff tissue as people age, matching the degeneration pattern seen in age-related tendinopathies.

Gender: In our study, a higher proportion of rotator cuff tears was observed in males (60.0%) compared to females (40.0%). This finding is consistent with the observations made by Singh et al. and Milgrom

et al. [9] However, Koganti et al.[2] reported no statistically significant differences in the incidence of rotator cuff lesions based on gender.

Site: In our study, the right shoulder was more frequently involved (70.0%) compared to the left shoulder (30.0%). This aligns with findings from Singh et al. [1] and Bouaziz et al. [10], where right shoulder involvement was also observed to be around 70.0% and 68.0% respectively.

Clinical symptom: In our study, the most common complaint of rotator cuff problems was pain, which aligns with findings from Koganti et al. [2]

Radiological Findings

In this study, rotator cuff tears were commonly observed as full-thickness defects in the tendon, extending from the bursal surface to its articular margin. Partial-thickness tears appeared as focal discontinuities in the tendon. On MRI, full-thickness tears were seen as hyperintense defects on T1W images, with the presence of hyperintense fluid supporting the diagnosis. Additional signs of complete tears included muscle retraction, fluid in the subacromial - subdeltoid bursa, and displacement of the peribursal fat plane.

Rotator cuff pathology

In our study, the supraspinatus tendon (65.4%) was the most affected, followed by the subscapularis (21.8%), infraspinatus (5.4%), and teres minor (3.6%). Similar findings were reported by Koganti et al. [2], with the highest abnormalities in the supraspinatus (57.7%) and subscapularis (29.5%), and lower rates for the infraspinatus. Walch et al. [11] found that only a small percentage (0.8%) of their study population had teres minor abnormalities on MRI. Other previous researchers have reported similar distribution pattern. [12,13]

In the present study, it was found that about a quarter of patients had rotator cuff problems in multiple tendons. This included a combination of pathology of PTT and FTT of the SST and tendinosis of SubT. This included a combination of pathology in the supraspinatus tendon and abnormalities in the subscapularis tendon, such as partial and full-thickness tears. Only few studies have previously reported involvement of multiple rotator cuff tendons. [14,15]

In the present study, 2/3rd of patients with SubT abnormalities also had PTT or FTT or tendinosis of SST. Lazaro R et al. [16] explained that this coexistence may be due to subacromial and sub-coracoid impingements. USG was found to be comparable to MRI in detecting FTT, PTT and tendinosis of SubT.

Accuracy of USG for detecting Rotator cuff pathology

In the present study, there was substantial agreement between US and MRI for diagnosis of RCT (k = 0.80). Similar result was observed in the study of Singh A et al.[1] (k = 0.79) and Alasaarela et al. [17] In the present study, Accuracy for RCT diagnosis by USG was higher for supraspinatus (98.0%) followed by infraspinatus (94.0%) and subcapsularis (90.0%). Sensitivity, specificity and predictive values were good in larger full-thickness tears compared to partial thickness tear, tendinosis. Agreement was also higher for larger full-thickness tears compared to partial thickness tear, and tendinosis particularly those involving the tendon of the subscapularis muscle.

Singisetti et al. [18] found that ultrasonography had good sensitivity (89%) and specificity (43%) in detecting supraspinatus, with higher sensitivity for larger full-thickness tears. Kamath et al. [19] reported accuracy of 70.6%, 90.6%, 85.4% and 76.35% for supraspinatus, infraspinatus, teres minor and subscapularis tendon injuries, respectively. Fischer et al. [20], also found high accuracy for detecting tears in supraspinatus tendon (91.1%), infraspinatus tendon (84.4%) subscapularis tendon (77.8%). Saraya et al. [21] found that ultrasound is as accurate as MRI for assessing rotator cuff tears both full- or partial-thickness tears. Meta-analysis by Roy et al. [22] confirmed high diagnostic accuracy for ultrasonography, MRI, and MR arthrography in characterizing full-thickness tears in individuals with shoulder pain.

Compared to MRI, USG was 100% accurate for detecting FTTs, 90.5% accurate for diagnosing PTTs and 96.0% accurate for identifying tendinosis of supraspinatus tendon. The findings of the present study correlates to previous studies. [23–25] In the present study, USG was 100% accurate in detecting FTT and tendinosis of IST. For PTTs of IST, The sensitivity to detect PTT was observed to be low. However, small sample size in this study may have underestimated the true sensitivity of USG in identifying PTT of IST.

Conclusion

There was good agreement (kappa value = 0.75) between ultrasound and MRI in diagnosing rotator cuff pathologies. Ultrasound is highly accurate in detecting most rotator cuff problems, except for subscapularis tendinosis and partial to full-thickness tears in the infraspinatus. A wide availability, lower cost and better tolerability of ultrasonography make it a modality of first choice for evaluation of rotator cuff tears. MRI can be reserved for patients with suspicious USG results.

References

1. Singh A, Thukral CL, Gupta K, Singh MI, Lata S, Arora RK. Role and correlation of high resolution ultrasound and magnetic resonance

imaging in evaluation of patients with shoulder pain. Polish J Radiol 2017 Jul 28;82410-7.
2. Koganti DV, Lamghare P, Parripati VK, Khandelwal R, Reddy AD. Role of magnetic resonance imaging in the evaluation of rotator cuff tears. Cureus 2022 Jan 8;14(1).e21025.
3. Teefey SA, Hasan SA, Middleton WD et al: Ultrasonography of the rotator cuff. J Bone Jt Surg Am, 2000; 82 498–504.
4. De Jesus JO, Parker L, Frangos AJ, Nazarian LN: Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. AJR Am J Roentgenol 2009, 1921701-7.
5. Morag Y, Jacobson JA, Miller B, Maeseneer MD, Girish G, et al. MR Imaging of rotator cuff injury: what the clinician needs to know. Radiogr 2006;261045–65.
6. Kaplan PA, Bryans KC, Davick JP, Otte M, Stinson WW, et al MR imaging of the normal shoulder: variants and pitfalls. Radiol 1992;184(2)519-524.
7. Moosikasuwan JB, Miller TT, Burke BJ. Rotator cuff tears: clinical, radiographic, and US findings. Radiogr 2005 Nov;25(6)1591-607.
8. Ozaki J, Fujimoto S, Nakagawa Y, et al.: Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. a study in cadavera. J Bone Jt Surg Am 19881, 701224-30.
9. Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M: Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. J Bone Jt Surg 1995; 77(2) 296–98.
10. Bouaziz M, Jabnoun F, Chaabane S, Ladeb MF: Diagnostic accuracy of high resolution ultrasound in communicating rotator cuff tears. Iran J Radiol, 2010; 7(3) 153–60.
11. Walch G, Boulahia A, Calderone S, Robinson AH: The “dropping” and “hornblower’s” signs in evaluation of rotator-cuff tears. J Bone Jt Surg Br 1998, 80624-8.
12. Shruthi GT, Amith R, Chowdhary AS, Sundeep SaC. Role of MRI in rotator cuff injuries. J Evid Based Med Heal 2018;5(32)23 94- 2401.
13. Singh P , Kaur A , Bhagat S , Singh GB , Gupta N. Role of ultrasound and MRI in patients with shoulder pathologies: a correlation study. Eur J Mol Clin Med 2021; 8(3)2890- 9.
14. Bartl C, Senftl M, Eichhorn S, Holzapfel K, Imhoff A, et al. Combined tears of the subscapularis and supraspinatus tendon: clinical outcome, rotator cuff strength and structural integrity following open repair. Arch Orthop Trauma Surg 2012;132(1)41-50.
15. Bhatnagar S, Kuber R, Shah D. The role of ultrasound and magnetic resonance imaging in the evaluation of musculotendinous pathologies of the shoulder joint. West Afr J Radiol 2014;2168-74.
16. Lazaro R. Shoulder impingement syndromes: implications on physical therapy examination and intervention. J Jpn Phys Ther Assoc 2005; 8(1)1-7.
17. Alasaarela E, Tervinene O, Takalo R et al: Ultrasound evaluation of the acromioclavicular joint. J Rheumatol 1997; 24(10) 1959–63.
18. Singisetti K, Hinsche A: Shoulder ultrasonography versus arthroscopy for the detection of rotator cuff tears: Anal errors J Orthop Surg, 2011; 19(1) 76–79.
19. Kamath SU, Chajed PK, Nahar VP: Correlation of clinical finding with ultrasound diagnosis of rotator cuff pathology. Research & Reviews: J Med Heal Sci 2014; 3(2).
20. Fischer CA, Weber MA, Neubecker C et al: Ultrasound vs. MRI in the assessment of rotator cuff structure prior to shoulder arthroplasty. J Orthop 2015; 12(1) 23–30.
21. Saraya S, Bakry RE: Ultrasound: Can it replace MRI in the evaluation of the rotator cuff tears. Egypt J Radiol Nucl Med 2016; 47 193–201.
22. Roy JS, Braën C, Leblond J et al: Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: A meta-analysis. Br J Sport Med, 2015; 49(20) 1316–28.
23. Gupta A, Nayak SR, Bahinipati P. Diagnostic accuracy of ultrasound in rotator cuff and associated non-rotator cuff pathologies of shoulder joint compared to magnetic resonance imaging. J Res Pract Musculoskelet Syst (JRPMS) 2022 Sep 1;6(3)72-82.
24. Malik P, Sen KK, Manoj KG, Mukherjee N, Veerabathini MK, et al. Accuracy of ultrasound compared to MRI in evaluation of rotator cuff tears. Int J Contemp Med Surg Radiol 2020;5(1)A21-A25.
25. Thakker VD, Bhuyan D, Arora M, Bora MI. Rotator cuff injuries: is ultrasound enough? A correlation with MR. Int J Anatomy, Radiol Surg 2017;6(3)1-7.