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Original article

Accuracy of Different Shoulder Scan Examination for Diagnosis of Rotator Cuff Pathologies: A Systematic and Meta-Analysis Review

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Abstract

Objectives: we aimed to compare the diagnosis accuracy between US and MRI in the diagnosis of full-thickness and partial-thickness rotator cuff tears and biceps tendon tears with arthroscopy used as the reference standard. ***Methodology:*** Comprehensive electronic search with time and language restrictions was conducted. Several known databases were included Ex: "PubMed, The Cochrane Library, Web of Science" from 2020 to 2020. We combined the search terms and limited the study to the English language. Depending on PRISMA checklist we would remove duplicates, articles would be screened based on title, abstract, and full text. ***Results:*** The electronic search strategy conducted in this review ended in 875 hits which after removing of duplicated reduced to 360 studies. These 360 studies were considered eligible for further evaluation, from which 348 studies were excluded for different reasons as 245 studies based on title and abstract, 86 studies do not relevant to the subject of this study or sitting of this review, 17 consider replies of authors, 2 books, and 28 were reviews. At end, 12 articles were included in the qualitative synthesis of the present review. ***Conclusion:*** we found that MRI had slightly better superiority than its accuracy, sensitivity and specificity especially, in Full and intact rotator cuff injuries. However, according to previous studies the use of US is still good because of its good sensitivity and specificity and cost- effective approach.

Introduction

Rotator cuff tears might cause substantial pain, reduced shoulder movement, and irreversible damage to glenohumeral joint [1]. Rotator cuff diseases are highly common and considered the most common cause of shoulder disabilities in the United States. Of the 4.5 million annual medical visits in the United States, approximately 30% to 70% are because of shoulder pain which is responsible for 70% of shoulder-related physician visits [2-4]. In a previous studies investigating the symptomatic and asymptomatic patients with mean age of 58 years old found that the prevalence of rotator cuff tears in the general population reached 21 % [5-7] with more than 270,000 surgeries related to rotator cuff performed annually and the process of diagnosis of rotator cuff injuries was responsible for more than 3 billion dollars to the annual health care costs in the United States only [8-10]. Because of this high prevalence of rotator cuff injuries and its economic burden, accurate and cost-effective methods for diagnosis is important for adequate patients' evaluation.

An accurate assessment of pathology of the rotator cuff is necessary to develop an algorithm approach to guide treatment strategies. Although magnetic resonance imaging (MRI) is the preferred imaging modality for rotator cuff tear in the United States, recent improvements in transducer strength as well as image resolution, and operator training have made ultrasound (US) a convenient, viable and cost-effective alternative to magnetic resonance imaging [6,11,12]. the cost of shoulder MRI as reported from the data of Centers for Medicare & Medicaid Services ranged between 303.51 and 387.01 Dollar while this for US ranged between $144 to $189.37. Studies show that this difference can be significant in private insurance, with an average MRI cost of $ 999.67 per patient [13]. US have also been shown to decrease patient wait times, enhance efficiency, and reduce health care costs [14]. For this reason, US has been increasingly being used in the diagnosis of both partial and full-thickness rotator cuff tears [15].

Although the US has shown promising potential for rotator cuff tear assessment, there are significant differences in the literature regarding US accuracy, sensitivity, and diversity in the diagnosis of total and partial thickness. In a 2015 meta-analysis, Roy et al [16] found that US accuracy and sensitivity were similar to MRI in the diagnosis of a rotator cuff tear. Previous systematic reviews have also supported this finding, although these meta-analyses varied in their study inclusion criteria [16-18]. The most recent systematic review by Liang et al [19] in 2020 found the sensitivity and specificity of US to be 0.95 and 0.72, respectively, for any-sized rotator cuff tear but did not separately evaluate diagnostic values for full- and partial-thickness tears. Moreover, this review was limited by a small study size and the inclusion of both arthroscopy and MRI as the reference standards [19]. In light of the rapid development of training and technology in the developed countries, an improved and comprehensive systematic review is needed to assess diagnostic accuracy of both of the available scanning tools of MRI and US for both full-thickness and partial-thickness rotator cuff injuries. In this

review, we aimed to compare the diagnosis accuracy between US and MRI in the diagnosis of full-thickness and partial-thickness rotator cuff tears and biceps tendon tears with arthroscopy used as the reference standard.

Methodology

This review was reported in the light of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.

- **Search methods for identification of studies**

A comprehensive electronic search with time and language restrictions was done. Several known databases were included Ex: "Google Scholar, PubMed, The Cochrane Library, Web of Science" from 2015 to 2020. Keyword that used include Shoulder pain, Rotator cuff, scan, US, MRI, accuracy, specificity, Error, diagnosis

Eligibility criteria and study selection

- **Inclusion criteria**
  - ☒ The study design was observational, case studies
  - ☒ Adult participants with shoulder pain
  - ☒ Used MRI, MRA or US as index test, and surgery (arthroscopy or open surgery) as reference standard
  - ☒ Reported on diagnostic accuracy of medical imaging for the characterisation of an RC disorder (tendinitis/tendinosis/tendinopathy (subacromial impingement syndrome), full or partial RC tears).
  - ☒ Published in English or Arabic but with English version
  - ☒ Published in a year between 2015 to 2020

- **Exclusion criteria**
  - ✓ Unpublished studies
  - ✓ Animal studies
  - ✓ Unsupported opinion of expert.
  - ✓ Replies to the author/editor.
  - ✓ Books'/conferences' abstracts.
  - ✓ Published in any language other than English
  - ✓ Published papers before 2015.

- **Data analysis**

In Several known database which was searched Ex: Google Scholar, PubMed, The Cochrane Library, Web of Science. We combined the search terms and limited the study to the English language. Depending on PRISMA checklist we removed duplicates, articles were screened based on title, abstract, and full text.

1. Study selection

The electronic search strategy conducted in this review ended in 875 hits which after removing of duplicated reduced to 360 studies. These 360 studies were considered eligible for further evaluation, from which 348 studies were excluded for different reasons as 245 studies based on title and abstract, 86 studies do not relevant to the subject of this study or sitting of this review, 17 consider replies of authors, 2 books, and 28 were reviews. At end, 11 articles were included in the qualitative synthesis of the present review (Figure 1).

2. General results

In this review, we included 12 studies [20,21,30,31,22-29] that had been conducted and published between 2015 and 2021 as shown in table 1. Among these studies, 2110 patients with rotator cuff injuries had been investigated either by MRI as shown in five studies or ultrasound scan (US) as shown in 12 studies. The mean age of patients among these studies was 51.78 years old ranging between 26.18 and 66 years old. In most studies, in order to calculate the specificity, accuracy and sensitivity of targeted scan, the results were compared with the results of arthroscopy. Supraspinatus injuries were the main type investigated in almost all studies.

Table 1: The general characteristic of the included studies and patients

#	Study	Year	Mean Patient Age, y	No. of Shoulders	Tear Type	Type of scanning	Specificity based on comparsion with	Tendons Evaluated	Tear Thickness
1	Mohtasib R	2019	53.7	86	Primary	US	MRI	Supraspinatus, Infraspinatus, Subscapularis	Any, FT, PT
2	Sabharwal et al.	2019	45	60	Primary	US, MRI	arthroscopy	Supraspinatus	FT, PT
3	Apostolopoulos et al	2019	56	19	Primary	US, MRI	arthroscopy	Supraspinatus	Any
4	Ron Gilat	2017	66	39	Revision	US	Surgery	Supraspinatus	FT, PT
5	Jonathan R.N.	2018	59.1	304	Primary	US, MRI	arthroscopy	Supraspinatus, Subscapularis	Any
6	Ahmed Elmorsy	2017	52	125	Primary	US, MRI	arthroscopy	Supraspinatus	FT, PT
7	Cole	2016	NS	238	Primary	US	arthroscopy	Supraspinatus	Any, full, partial
8	Kurz A	2016	62	755	Primary	US	arthroscopy	Supraspinatus	FT, PT
9	R. Narasimhan	2016	NS	236	Primary	US	arthroscopy	Subscapularis	Any
10	Li-Ping Guo	2015	53	173	Primary	US	arthroscopy	Supraspinatus	PT
11	Haytham Abdel-Moneim	2019	26.18	45	Primary	US, MRI	arthroscopy	Subscapularis, Supraspinatus, infraspinatus	Any
12	Medhat M. Refaat	2020	45	30	Primary	US	arthroscopy	Supraspinatus	FT, PT

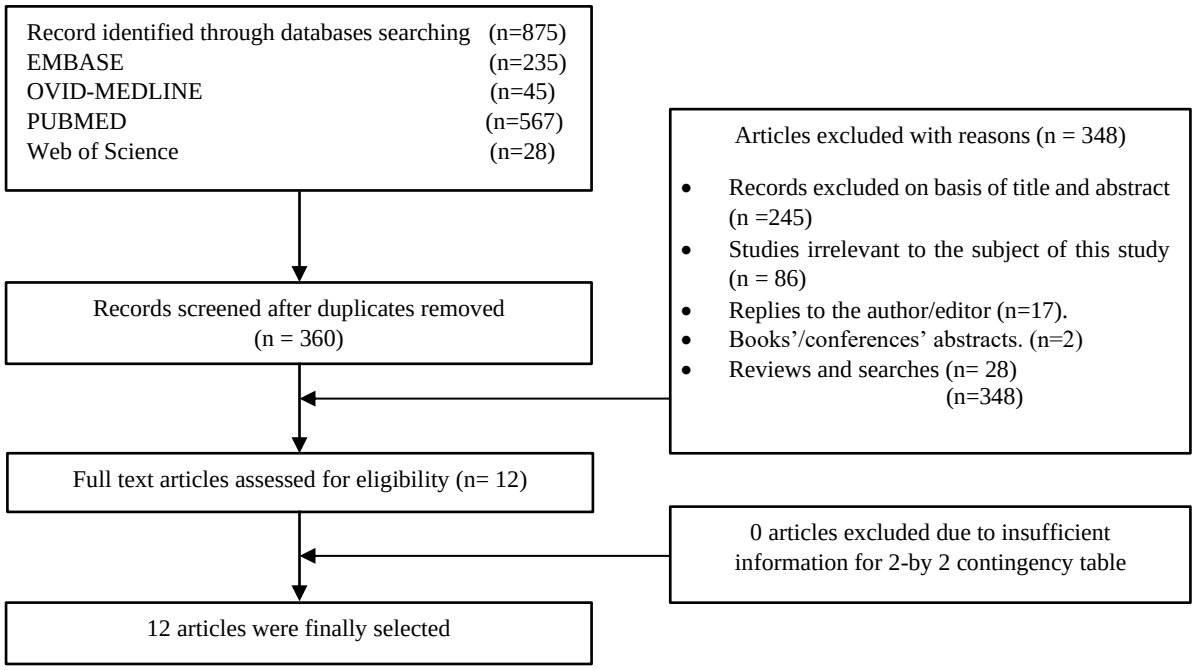

Figure 1The PRISMA figures showing the steps to choose the studies for systematic review.

3. The specific results of the pooled studies

In this review, we compared the diagnostic value of both MRI and US for patients with rotator cuff tears. For patients with any-sized supraspinatus rotator cuff tear, the mean accuracy, sensitivity, specificity of MRI were 82.65 (0.65), 90.65 (4.35), 64.25 (8.25) while the mean accuracy, sensitivity, and specificity of US of the same injury were 78.5 (11.5), 81.05 (13), 62.2 (17.5) respectively. As shown in table 2, there is significant difference between the results of both scans where MRI had a significantly higher rates of accuracy and sensitivity than US with no significant difference in specificity. Considering the subscapularis any sized rotator cuff tears, the accuracy, sensitivity, and specificity of MRI were 79.8 (6.8), 57.65 (28.05), 88.3 (0.85) compared with accuracy, sensitivity and specificity of US of 67.7 (17.3), 70.85 (33.8) and 66.3 (29.7) respectively with significant difference between the results of the two scans with favored results for MRI considering accuracy and specificity and lower sensitivity than US (**Table 2**).

Table 2: The diagnostic value of MRI and US in diagnosis of supraspinatus and subscapularis any sized rotator cuff tears

Any-Sized Rotator Cuff or Biceps Tear										
	Supraspinatus					Subscapularis				
	MRI		US		P-value	MRI		US		P-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
No. of studies (shoulders)	2		4			2		4		
Diagnostic values										
Diagnostic accuracy	82.65	0.65	78.5	11.5	0.001*	79.8	6.8	67.7	17.3	0.001*
Sensitivity	90.65	4.35	81.05	13	0.001*	57.65	28.05	70.85	33.8	0.001*
Specificity	64.25	8.25	62.225	17.5	0.151	88.35	0.85	66.275	29.7	0.007*
NPV	93.5	0.57	85.3	15.2	0.001*	51.6	0.0	56.23	19.5	0.001*
PPV	56.9	19.1	49.57	27.5	0.007*	76.5	0.0	61.06	23.6	0.001*

Considering the results of both scans in full and partial rotator cuff, results were showed in table 3. The mean accuracy, sensitivity and specificity of MRI in full supraspinatus rotator cuff were 82.8 (13.8), 91.8 (2.55), 89.8 (10.1) while the mean accuracy, sensitivity, specificity of US in the same condition were 86.1 (10), 67.1 (35.2), and 93.6 (7.86) respectively. The results showed that there is a significant difference between the results of two scans with higher accuracy and specificity of US scans and higher sensitivity of MRI. In partial supraspinatus rotator cuff, the accuracy, sensitivity and specificity of MRI were 72 (17.9), 78.8 (6.2), and 90 (2.5) compared with mean accuracy, sensitivity and specificity of US of 67.3 (25), 80.9 (18.5) and 89.68 (10.3) respectively. No significant difference was found between the sensitivity and specificity results of both scans and accuracy mean of MRI was significantly higher than mean of US (**Table 3**).

Table 2: The diagnostic value of MRI and US in diagnosis of supraspinatus full and partial rotator cuff tears

Full and Partial Rotator Cuff										
	Full Supraspinatus				P-value	Partial supraspinatus				P-value
	MRI		US			MRI		US		
No. of studies (shoulders)	2		6			2		7		
Diagnostic values										
Diagnostic accuracy	82.85	13.85	86.1	10	0.006*	72.05	17.95	67.3	25.03	0.007*
Sensitivity	91.85	2.55	67.1	35.2	0.001*	78.8	6.2	80.9	18.5	0.092
Specificity	89.85	10.15	93.68	7.86	0.007*	90	2.5	89.68	10.3	0.678

NPV	87.45	4.85	95	6.23	0.008*	57.95	27	75.06	29.3	0.001*
PPV	100	0	75.5	28.64	0.001*	92	0	77.825	20.2	0.001*

Discussion

This review of literature resulted in the superiority of MRI in the diagnosis of intact and full supraspinatus rotator cuff injuries than US with no significant difference in case of partial rotator cuff injuries. However, the superiority of MRI, we found that sensitivity and specificity of US is good especially for partial rotator cuff tears with mean sensitivity and specificity of 80.9 and 89 and 68 respectively. These results are in agreement with the results of previous systematic reviews [17,18,32–34]. In previous study conducted by Harmon Kg, the author found that the overall range of the sensitivity of MRI in the diagnosis of any rotator cuff tears was 98 and overall specificity of 79 [35] which is slightly different from our results which showed a sensitivity and specificity of MRI in any RC tears of 91.8 and 89.8. Moreover, in previous two systematic reviews conducted by Smith et al, the authors reported similar results as those reported in our revie including these results for partial thickness rotator cuff tears for US where differences were noted in superiority for US. They obtained an overall estimate of sensitivity of 84 compared to 80.9 in the present study. [34,36]. The good sensitivity and specificity of US in diagnosis of full-thickness supraspinatus rotator cuff tears found in this study is consistent with previous systematic review and meta-analysis [16,17,31,37]. However, the US found to have lower mean sensitivity and specificity for partial thickness tears than full thickness rotator cuff tears which is supported by the results of previous study in which the authors found that diagnostic accuracy of US increased with tear size for full-thickness supraspinatus tears [38]. One of the factors that could explain the lower sensitivity of US for partial thickness tears is the variable echogenicity of the synovial proliferation, scare tissue formation as well as granulation surrounding the partial tear reducing the ability to clear tissue differentiation [39]. Moreover, previous studies found that US had high specificity and low sensitivity considering the diagnosis of the entire spectrum of subscapularis tearing, including full or partial tears [40,41]. Significant contribution to lower sensitivity for subscapularis tear is that the US has reduced access to the subscapularis region compared to other rotator cuff ligaments [42]. Previous studies have shown that MRI shows the same low sensitivity to detect subscapular tears [43]. Three studies reported on the diagnostic outcomes of US evaluation of tears of the long head of the biceps brachii (LHB) tendon [18,44,45]. Skendzel et al reported high accuracy in diagnosing LHB tendinitis without complete fractures and tendons but partial thickness LHB tendons are difficult to distinguish from other diseases, such as tendonitis and tenosynovitis [46]. The evaluation of both subclinical ligaments and ligaments of LHB does not have a weak representation in the literature, and further studies are needed to clearly determine the accuracy of the diagnosis in the US. With high variability and low US capillary and biceps sensitivity, we recommend using the US as a diagnostic imaging method but not as a diagnostic test for patients with suspected pathology.

From these findings, US and MRI can be considered as special tools to diagnose rotator cuff disorders, but in most cases they are very sensitive to full thickness RC tears. In addition to the cost of diagnosis, several factors must be considered to evaluate the clinical implications of these findings. Clinical management outcomes are key to safety, cost, availability, and impact. In terms of safety, US and MRI scans are not invasive, with the exception of certain MRI scans. Claustrophobia can be a problem with MRI and MRA scans. Although MRI shows slightly better performance, this procedure involves intravenous injections that may cause discomfort (risk, infection) for patients. When considering cost and availability, these tests can be divided into most settings as follows: US <MRI [47,48]. Finally, and perhaps most important when imaging RC lesions, one should consider the impact of test results on clinical management.

Reassembly, tendinopathy while RC repair surgery is widely considered to be in cases of full-thickness RC tears that are related to a number of criteria such as duration (acute vs chronic), age, function, pain and size of tear [49]. The most clinically significant feature when choosing a shoulder imaging mode for RC disorder assessment is thus the capacity to properly detect a full-thickness RC tear because it represents a key indication for surgical repair [50]. Consequently, the most clinically significant aspect of this meta-analysis is the information associated with capacity of the tests documenting full-thickness RC tears. The use of ultrasound at the point of care must be linked to specific training that should be defined in curriculum such as the one recently updated by the American Medical Society for Sports Medicine (AMSSM) [51]. Finally, diagnostic use of US at the point of care can also lead to improved therapeutic efficiency through the immediate use of interventions such as injections, which have been shown to be more effective under US guidance [52-54].

The use of US, giving equivalent information to MRI but less costly, is why it is the recommended diagnosis of RC disorders. These conclusions are consistent with the imaging algorithms for evaluating suspected RC disease suggested by the Society of Radiologists in Ultrasound [50]. Additionally, clinical situations where other shoulder conditions such as articular cartilage injuries or labral tears must be considered (eg, in cases where glenohumeral instability in younger patients or osteoarthritis in older patients overlap with RC disorders) could justify the use of MRI or MRA. However, in most conditions, first we support a combination of different non-invasive and less expensive clinical evaluation tests before the use of medical imaging, as these tests are mostly appropriate for confirming a number of specific RC pathologies. However, in situations of acute shoulder injuries where full thickness RC tears is considered, imaging must be obtained rapidly as rapid repair of a ‘fresh’ tear on a previously healthy RC has the best prognosis.

In conclusion, we found that MRI had slightly better superiority than its accuracy, sensitivity and specificity especially, in Full and intact rotator cuff injuries. However, according to previous studies the use of US is still good because of its good sensitivity and specificity and cost- effective approach.

Conflicts of Interest

None

Funding Statement

None

References

[1] Nathani A, Smith K, Wang T. Partial and Full-Thickness RCT: Modern Repair Techniques. Curr Rev Musculoskelet Med. 2018;11(1):113-121. doi:10.1007/s12178-018-9465-4

[2] Rees JL. The pathogenesis and surgical treatment of tears of the rotator cuff. J Bone Joint Surg Br. 2008;90-B(7):827-832. doi:10.1302/0301-620X.90B7.19874

[3] Oh LS, Wolf BR, Hall MP, Levy BA, Marx RG. Indications for Rotator Cuff Repair. Clin Orthop Relat Res. 2007;455:52-63. doi:10.1097/BLO.0b013e31802fc175

[4] Mitchell C, Adebajo A, Hay E, Carr A. Shoulder pain: diagnosis and management in primary care. BMJ.

2005;331(7525):1124-1128. doi:10.1136/bmj.331.7525.1124

[5] Ward JRN, Lotfi N, Dias RG, McBride TJ. Diagnostic difficulties in the radiological assessment of subscapularis tears. J Orthop. 2018;15(1):99-101. doi:10.1016/j.jor.2018.01.016

[6] Teefey SA, Middleton WD, Yamaguchi K. SHOULDER SONOGRAPHY. Radiol Clin North Am. 1999;37(4):767-785. doi:10.1016/S0033-8389(05)70128-7

[7] Tashjian RZ. Epidemiology, Natural History, and Indications for Treatment of Rotator Cuff Tears. Clin Sports Med. 2012;31(4):589-604. doi:10.1016/j.csm.2012.07.001

[8] Savoie FH, Field LD, Nan Jenkins R. Costs analysis of successful rotator cuff repair surgery: An outcome study. Comparison of gatekeeper system in surgical patients. Arthrosc J Arthrosc Relat Surg. 1995;11(6):672-676. doi:10.1016/0749-8063(95)90107-8

[9] Sabesan VJ, Shahriar R, Chatha K, et al. Factors Affecting the Cost and Profitability of Arthroscopic Rotator Cuff Repair. Arthrosc J Arthrosc Relat Surg. 2019;35(1):38-42. doi:10.1016/j.arthro.2018.07.034

[10] Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National Trends in Rotator Cuff Repair. J Bone Jt Surgery-American Vol. 2012;94(3):227-233. doi:10.2106/JBJS.J.00739

[11] Middleton WD, Edelstein G, Reinus WR, Melson GL, Murphy WA. Ultrasonography of the rotator cuff: technique and normal anatomy. J Ultrasound Med. 1984;3(12):549-551. doi:10.7863/jum.1984.3.12.549

[12] Rutten MJCM, Jager GJ, Kiemeney LALM. Ultrasound Detection of Rotator Cuff Tears: Observer Agreement Related to Increasing Experience. Am J Roentgenol. 2010;195(6):W440-W446. doi:10.2214/AJR.10.4526

[13] Yeranosian MG, Terrell RD, Wang JC, McAllister DR, Petrigliano FA. The costs associated with the evaluation of rotator cuff tears before surgical repair. J Shoulder Elb Surg. 2013;22(12):1662-1666. doi:10.1016/j.jse.2013.08.003

[14] Chiu C-H, Chen P, Chen AC-Y, et al. Shoulder ultrasonography performed by orthopedic surgeons increases efficiency in diagnosis of rotator cuff tears. J Orthop Surg Res. 2017;12(1):63. doi:10.1186/s13018-017-0565-4

[15] Bouffard JA, Lee S-M, Dhanju J. Ultrasonography of the shoulder. Semin Ultrasound, CT MRI. 2000;21(3):164-191. doi:10.1016/S0887-2171(00)90041-6

[16] Roy J-S, Braën C, Leblond J, et al. Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: a systematic review and meta-analysis. Br J Sports Med. 2015;49(20):1316-1328. doi:10.1136/bjsports-2014-094148

[17] Lenza M, Buchbinder R, Takwoingi Y, Johnston R V, Hanchard NC, Faloppa F. Magnetic resonance imaging, magnetic resonance arthrography and ultrasonography for assessing rotator cuff tears in people with shoulder pain for whom surgery is being considered. Cochrane Database Syst Rev. Published online September 24, 2013. doi:10.1002/14651858.CD009020.pub2

[18] Ottenheijm RP, Jansen MJ, Staal JB, et al. Accuracy of Diagnostic Ultrasound in Patients With Suspected Subacromial Disorders: A Systematic Review and Meta-Analysis. Arch Phys Med Rehabil. 2010;91(10):1616-1625. doi:10.1016/j.apmr.2010.07.017

[19] Liang W, Wu H, Dong F, Tian H, Xu J. Diagnostic performance of ultrasound for rotator cuff tears: a systematic review and meta-analysis. Med Ultrason. 2020;22(2):197. doi:10.11152/mu-2352

[20] Abdel-Moneim H. Reliability of specific clinical tests and MRI in the diagnosis of rotator cuff tears in comparison with arthroscopy. Egypt Orthop J. 2019;54(1):79. doi:10.4103/eoj.eoj_8_19

[21] Modipalli D, Hegde AS, Shetty CB. Diagnostic accuracy in rotator cuff tears: clinical tests vs MRI. Int J Res Orthop. 2019;5(4):727. doi:10.18203/issn.2455-4510.intjresorthop20192693

[22] Narasimhan R, Shamse K, Nash C, Dhingra D, Kennedy S. Prevalence of subscapularis tears and accuracy of shoulder ultrasound in pre-operative diagnosis. Int Orthop. 2016;40(5):975-979. doi:10.1007/s00264-015-3043-9

[23] Kurz AZ, Kelly MJ, Hackett L, Murrell GAC. Effect of surgeon-sonographer interaction on ultrasound diagnosis of rotator cuff tears: a five-year cohort study in 775 shoulders. J Shoulder Elb Surg. 2016;25(9):1385-1394. doi:10.1016/j.jse.2016.04.027

[24] Cole B, Twibill K, Lam P, Hackett L, Murrell GAC. Not all ultrasounds are created equal: general sonography versus musculoskeletal sonography in the detection of rotator cuff tears. Shoulder Elb. 2016;8(4):250-257. doi:10.1177/1758573216658800

[25] Elmorsy A, Keightley A, Flannery M. Accuracy of ultrasonography (US) and magnetic resonance imaging (MRI) in detection of rotator cuff tears in district general hospital. Polish J Radiol. 2017;82:634-637. doi:10.12659/PJR.903004

[26] Ward JRN, Lotfi N, Dias RG, McBride TJ. Diagnostic difficulties in the radiological assessment of subscapularis tears. J Orthop. 2018;15(1):99-101. doi:10.1016/j.jor.2018.01.016

[27] Gilat R, Atoun E, Cohen O, et al. Recurrent rotator cuff tear: is ultrasound imaging reliable? J Shoulder Elb Surg. 2018;27(7):1263-1267. doi:10.1016/j.jse.2017.12.017

[28] Apostolopoulos AP, Angelis S, Yellapragada RK, et al. The Sensitivity of Magnetic Resonance Imaging and Ultrasonography in Detecting Rotator Cuff Tears. Cureus. 2019;11(5):1-10. doi:10.7759/cureus.4581

[29] Sabharwal T, Khanduri S, Khan S, et al. A Comparative Assessment Between High-resolution Ultrasonography and Field Magnetic Resonance Imaging in Supraspinatus Tear Cases and Its Arthroscopic Correlation. Cureus. 2019;11(9). doi:10.7759/cureus.5627

[30] Mohtasib RS, Alzahrani AM, Asiri YN, Rayes ZF, Alshaalan MA. Accuracy of shoulder ultrasound examination for diagnosis of rotator cuff pathologies: A single-center retrospective study. Ann Saudi Med. 2019;39(3):162-171. doi:10.5144/0256-4947.2019.162

[31] Okoroha KR, Fidai MS, Tramer JS, Davis KD, Kolowich PA. Diagnostic accuracy of ultrasound for rotator cuff tears. Ultrasonography. 2019;38(3):215-220. doi:10.14366/usg.18058

[32] 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. Am J Roentgenol. 2009;192(6):1701-1707. doi:10.2214/AJR.08.1241

[33] Dinnes J, Loveman E, McIntyre L, Waugh N. The effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders: a systematic review. Health Technol Assess (Rockv). 2003;7(29). doi:10.3310/hta7290

[34] Smith TO, Back T, Toms AP, Hing CB. Diagnostic accuracy of ultrasound for rotator cuff tears in adults: A

systematic review and meta-analysis. Clin Radiol. 2011;66(11):1036-1048. doi:10.1016/j.crad.2011.05.007

[35] Harmon KG, O'Connor FG. Musculoskeletal ultrasound: taking sports medicine to the next level. Br J Sports Med. 2010;44(16):1135-1136. doi:10.1136/bjsm.2010.080796

[36] Smith TO, Daniell H, Geere J-A, Toms AP, Hing CB. The diagnostic accuracy of MRI for the detection of partial- and full-thickness rotator cuff tears in adults. Magn Reson Imaging. 2012;30(3):336-346. doi:10.1016/j.mri.2011.12.008

[37] Liu F, Dong J, Shen W-J, Kang Q, Zhou D, Xiong F. Detecting Rotator Cuff Tears: A Network Meta-analysis of 144 Diagnostic Studies. Orthop J Sport Med. 2020;8(2):232596711990035. doi:10.1177/2325967119900356

[38] Cowling P, Gamble A, Rangan A. The use of Shoulder Ultrasound in a One-Stop Clinic: Diagnostic Accuracy for Rotator Cuff Tear and Biceps Tendon Pathology. Shoulder Elb. 2011;3(1):13-16. doi:10.1111/j.1758-5740.2010.00092.x

[39] Ok J-H, Kim Y-S, Kim J-M, Yoo T-W. Learning curve of office-based ultrasonography for rotator cuff tendons tears. Knee Surgery, Sport Traumatol Arthrosc. 2013;21(7):1593-1597. doi:10.1007/s00167-012-2105-4

[40] Moosmayer S, Smith H. Diagnostic ultrasound of the shoulder—a method for experts only? Acta Orthop. 2005;76(4):503-508. doi:10.1080/17453670510041484

[41] Zehetgruber H, Lang T, Wurnig C. Distinction between supraspinatus, infraspinatus and subscapularis tendon tears with ultrasound in 332 surgically confirmed cases. Ultrasound Med Biol. 2002;28(6):711-717. doi:10.1016/S0301-5629(02)00508-2

[42] Leeflang MMG. Systematic reviews and meta-analyses of diagnostic test accuracy. Clin Microbiol Infect. 2014;20(2):105-113. doi:10.1111/1469-0691.12474

[43] Neer CS. Impingement lesions. Clin Orthop Relat Res. 1983;(173):70-77. http://www.ncbi.nlm.nih.gov/pubmed/6825348

[44] Hitachi S, Takase K, Tanaka M, et al. High-resolution magnetic resonance imaging of rotator cuff tears using a microscopy coil: noninvasive detection without intraarticular contrast material. Jpn J Radiol. 2011;29(7):466-474. doi:10.1007/s11604-011-0583-9

[45] Balich SM, Sheley RC, Brown TR, Sauser DD, Quinn SF. MR imaging of the rotator cuff tendon: interobserver agreement and analysis of interpretive errors. Radiology. 1997;204(1):191-194. doi:10.1148/radiology.204.1.9205245

[46] Skendzel JG, Jacobson JA, Carpenter JE, Miller BS. Long Head of Biceps Brachii Tendon Evaluation: Accuracy of Preoperative Ultrasound. Am J Roentgenol. 2011;197(4):942-948. doi:10.2214/AJR.10.5012

[47] Parker L, Nazarian LN, Carrino JA, et al. Musculoskeletal Imaging: Medicare Use, Costs, and Potential for Cost Substitution. J Am Coll Radiol. 2008;5(3):182-188. doi:10.1016/j.jacr.2007.07.016

[48] Nazarian LN, Jacobson JA, Benson CB, et al. Imaging Algorithms for Evaluating Suspected Rotator Cuff Disease: Society of Radiologists in Ultrasound Consensus Conference Statement. Radiology. 2013;267(2):589-595. doi:10.1148/radiol.13121947

[49] Marx RG, Koulouvaris P, Chu SK, Levy BA. Indications for Surgery in Clinical Outcome Studies of Rotator Cuff Repair. Clin Orthop Relat Res. 2009;467(2):450-456. doi:10.1007/s11999-008-0585-9

[50] Lambers Heerspink FO, Dorrestijn O, van Raay JJAM, Diercks RL. Specific patient-related prognostic factors for rotator cuff repair: a systematic review. J Shoulder Elb Surg. 2014;23(7):1073-1080. doi:10.1016/j.jse.2014.01.001

[51] Finnoff J, Lavallee ME, Smith J. Musculoskeletal ultrasound education for sports medicine fellows: a suggested/potential curriculum by the American Medical Society for Sports Medicine. Br J Sports Med. 2010;44(16):1144-1148. doi:10.1136/bjsm.2010.078857

[52] Lasbleiz S, Quintero N, Ea K, et al. Diagnostic value of clinical tests for degenerative rotator cuff disease in medical practice. Ann Phys Rehabil Med. 2014;57(4):228-243. doi:10.1016/j.rehab.2014.04.001

[53] Aly A-R, Rajasekaran S, Ashworth N. Ultrasound-guided shoulder girdle injections are more accurate and more effective than landmark-guided injections: a systematic review and meta-analysis. Br J Sports Med. 2015;49(16):1042-1049. doi:10.1136/bjsports-2014-093573

[54] Finnoff JT, Hall MM, Adams E, et al. American Medical Society for Sports Medicine (AMSSM) Position Statement: Interventional Musculoskeletal Ultrasound in Sports Medicine. PM&R. 2015;7(2):151-168.e12. doi:10.1016/j.pmrj.2015.01.003