

Imaging of the Shoulder: A Comparison of MRI and Ultrasound

Benjamin D. Levine, MD¹; Kambiz Motamedi, MD²; and Leanne L. Seeger, MD³

Abstract

Magnetic resonance imaging (MRI) is well established as a powerful imaging modality for the shoulder. In the last decade, ultrasound has emerged as an effective imaging option, alongside MRI, for evaluation of the shoulder. With MRI and ultrasound, clinicians now have two viable advanced imaging options for the diagnostic evaluation of shoulder pain. This article discusses the advantages and disadvantages of ultrasound and MRI for the shoulder. Applications where ultrasound is considered the imaging test of choice, those where MRI is more advantageous, and those where both ultrasound and MRI are viable alternatives for shoulder imaging are discussed.

Introduction

The role of diagnostic imaging in the evaluation of shoulder pain is to guide clinical management. In the presence of a rotator cuff tear, imaging can determine whether the tear is full thickness or partial thickness and thus help the clinician decide between operative or nonoperative treatment (20). If surgical treatment is decided, imaging can be used further to plan the surgical approach whether it be open or arthroscopic. Currently magnetic resonance imaging (MRI) and ultrasound are the most commonly used cross-sectional imaging modalities in the diagnostic work-up of shoulder pain.

Since its introduction in the 1980s, MRI has revolutionized musculoskeletal cross-sectional imaging of the shoulder. MRI is well established as an effective and comprehensive imaging modality for the evaluation of shoulder abnormalities. In the United States, MRI is considered the imaging test of choice for articular cartilage, bone marrow, and most ligament abnormalities (8). Compared with ultrasound, MRI

offers a more comprehensive evaluation of the bones and deep soft tissues about the shoulder, as it capitalizes on areas where ultrasound is limited. These include the bones, articular cartilage, and the labrum.

Although MRI is well suited to evaluate the shoulder, interest in and utilization of ultrasound for shoulder imaging has increased dramatically since it was introduced first in the late 1970s. This is likely the result of improved access to ultrasound examination as

well as marked improvements in ultrasound technology including high-resolution transducers. Such transducers now can achieve resolution on the order of 200 μm , greater than that obtainable with MRI (8). Other improvements in ultrasound that have contributed to its increased popularity for musculoskeletal imaging are power Doppler and extended field-of-view imaging. In addition, ultrasound machines have become more portable and more ergonomic while maintaining their relative power, all at a lower cost per examination when compared with MRI.

Diagnostic Efficacy: The Rotator Cuff

Many studies have compared the accuracy of ultrasound with MRI with regard to the shoulder, and particularly the rotator cuff (11). Reported sensitivities and accuracies are variable due to many factors. First the experience of the sonographer significantly can affect results. Improper training of sonographers with regard to musculoskeletal imaging will produce nonstandardized and nonreproducible images resulting in inaccurate image interpretation. Other factors that affect such studies include variable gold standards, different study designs, varying image equipment quality, and different diagnostic criteria. However with proper training and standardized technique, the literature would suggest that high accuracies, comparable with MRI, are attainable with ultrasound for the diagnosis of rotator cuff tears (8).

Several studies have looked at the efficacy of ultrasound for diagnosing rotator cuff tears compared with surgical findings. The diagnostic efficacy of ultrasound for full-thickness tears is well documented with accuracies reported up to 96% (8,22). For partial-thickness tears, accuracies of up to 94% have been reported using ultrasound (23). These

¹Department of Radiology, David Geffen School of Medicine at UCLA, UCLA-Santa Monica Medical Center and Orthopedic Hospital, Santa Monica, CA 90404; ²Department of Radiology, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095-6952; and ³Department of Radiology, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095-6952

Address for correspondence: Benjamin D. Levine, MD, Department of Radiology, David Geffen School of Medicine at UCLA, UCLA-Santa Monica Medical Center and Orthopedic Hospital, 1250 16th Street, Suite 2340, Santa Monica, CA 90404; E-mail: blevine@mednet.ucla.edu

1537-890X/1105/239-243

Current Sports Medicine Reports

Copyright © 2012 by the American College of Sports Medicine

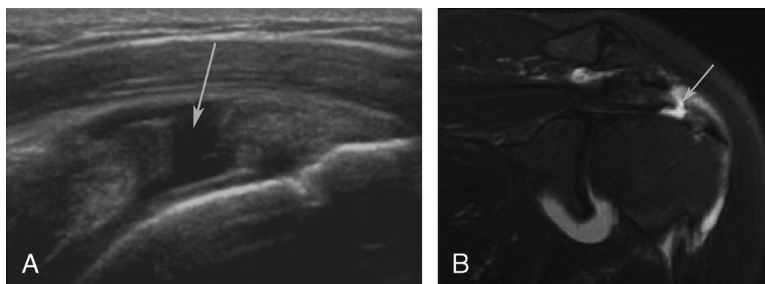


Figure 1: A. Longitudinal ultrasound image of the supraspinatus tendon demonstrates a full-thickness tear (*arrow*) near the footprint. B. MRI in the same patient also shows the full-thickness supraspinatus tear (*arrow*) with nearly identical morphology.

are comparable with accuracies using MRI for both full-thickness (92% to 97%) and partial-thickness (92%) tears (1,8) (Fig. 1). Overall, reported sensitivities of ultrasound for the diagnosis of rotator cuff tears have ranged from 33% to 100% (9), likely for the reasons previously discussed.

Although questions have been raised in the literature regarding the utility of ultrasound for partial-thickness tears (15), the majority of studies continue to find comparable accuracies of ultrasound and MRI for partial-thickness tears. Vlychou *et al.* (24) evaluated the diagnostic performance of ultrasound and MRI for symptomatic partial rotator cuffs tears with surgical correlation and found almost equal efficacy of the two modalities. In fact, this study found that the specificity of ultrasound for partial rotator cuff tears actually exceeded that of MRI. In addition, this study showed a higher positive predictive value for partial rotator cuff tears using ultrasound compared with MRI. This would suggest that when a rotator cuff tear is suspected clinically, ultrasound can support the diagnosis with confidence, even for partial-thickness tears.

In a recent meta-analysis, de Jesus *et al.* (4) reviewed 65 articles reporting the sensitivities and specificities of MRI, ultrasound, and magnetic resonance (MR) arthrography for the diagnosis of rotator cuff tears with surgery as a reference standard. They found that reported sensitivities and specificities for ultrasound varied between 60% and 100%, with similar varied ranges for MRI and MR arthrography. Drawing on the strengths of a meta-analysis, this study found no statistically significant difference in either sensitivity or specificity between MRI and ultrasound for the diagnosis of partial or full-thickness rotator cuff tears. It found ultrasound to be as accurate as MRI for both full-thickness and partial-thickness tear diagnoses.

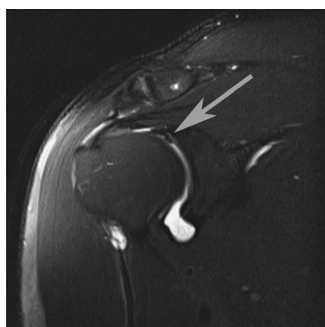


Figure 2: Coronal oblique MRI image from an arthrogram demonstrates a superior labral tear (SLAP) (*arrow*).

One other meta-analysis has been published evaluating ultrasound, MRI, and MR arthrography for rotator cuff tears (9). Although this study did not use surgery as the reference standard, this study concluded that both ultrasound and MRI had equal detection rates for full-thickness rotator cuff tears (5).

Observer Variability

When comparing MRI and ultrasound, the issue of observer variability must be considered. Assuming the MRI technologist is trained to produce standard imaging planes and sequences with appropriate coils, observer variability with MRI is at the level of image interpretation with the radiologist. In contrast, observer variability with ultrasound is influenced at several levels (8). First the sonographer must understand anatomy both in static and dynamic situations to locate the area of interest. They must further be able to evaluate the area of interest in a standard plane and recognize artifacts such as anisotropy and correct for them. Then, finally, in the case of physician sonographers, they must interpret the produced image.

Many studies have evaluated observer variability with regard to musculoskeletal ultrasound. Middleton *et al.* (17) reported 80% agreement between two observers in the evaluation of the rotator cuff. Le Corroller *et al.* (14) compared observers with different levels of musculoskeletal ultrasound experience for the evaluation of the shoulder and

Table 1.
Applications of MRI and ultrasound for the shoulder.

	MRI	Ultrasound
Labrum	+++	+
Articular cartilage	+++	0
Bone marrow	+++	0
Deep soft tissues	+++	+
Foreign bodies	+	+++
Soft tissues around hardware	+	+++
Dynamic imaging	0	+++
Guided procedures	0	+++
Cyst versus solid	++	+++
Focal tendon abnormality	+++	+++

+++ , excellent; ++ , good; + , limited; 0 , suboptimal/not applicable.

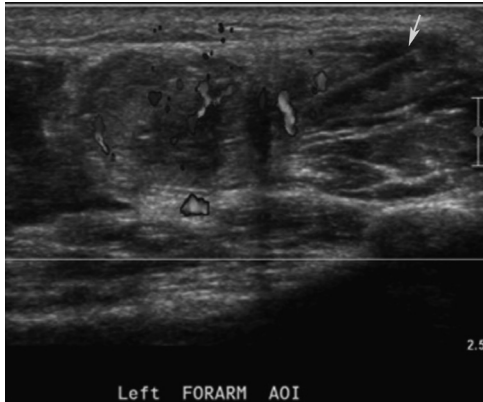


Figure 3: Ultrasound image with Doppler demonstrates the hyperechoic foreign body (*arrow*) with surrounding hyperemia. This was consistent with a palm frond and was not seen with plain radiographs.

found very good agreement for full-thickness rotator cuff tears ($\kappa = 0.90$) and moderate agreement for partial-thickness tears ($\kappa = 0.63$). Although observer variability is an obvious issue intrinsic to the efficacy of musculoskeletal ultrasound imaging, it also exists with MRI. Minimizing observer variability is critical to optimal imaging with ultrasound and MRI and likely depends on proper training.

Applications

For shoulder imaging, MRI offers a more global, comprehensive evaluation than ultrasound as it includes areas where ultrasound is limited. Such areas where MRI excels and ultrasound falls short are intraarticular structures (articular cartilage and labrum), bone marrow, and deep soft tissues. For example, if the clinical suspicion is that of a labral tear in a patient younger than 40 years, MRI is the test of choice (Fig. 2). MRI also would be indicated over ultrasound if there is concern for a neoplastic process, particularly if it involves the bone marrow. MRI also would be the test of choice for other intraarticular abnormalities such as intraarticular bodies or articular cartilage loss.

There are several situations where ultrasound has advantages over MRI. These include evaluation of soft tissue foreign bodies, soft tissues near hardware, and abnormalities that necessitate a specific extremity dynamic maneuver

Table 2.

Other reasons to perform shoulder ultrasound instead of MRI.

Transducer can be placed exactly at the site of pain

More flexible field of view

Bilateral comparison available

Patient with cardiac pacemaker

Patient with metal implant not MRI compatible

Patient with claustrophobia

or position to provide the diagnosis, and for guided procedures (8) (Table 1).

With regard to soft tissue foreign bodies, the high resolution of ultrasound can detect foreign bodies as small as 0.5 mm (6). All soft tissue foreign bodies are initially hyperechoic and often are surrounded by a hypoechoic halo with surrounding increased color or power Doppler flow (Fig. 3). Ultrasound can localize the foreign body, can be used to mark the skin for surgical planning, and can identify complications such as an abscess or tenosynovitis (2).

Ultrasound also is suited ideally to evaluate soft tissues around metal hardware (10). Although metal artifact reduction sequences with MRI have improved, ultrasound is less susceptible to metal artifact because the artifact occurs deep to the metal. Consequently the tissues superficial to the metal such as tendons, ligaments, or soft tissues can be evaluated well (Fig. 4). In fact, ultrasound is the test of choice to evaluate the rotator cuff in patients who have undergone prior arthroplasty (21).

Ultrasound has clear advantages over MRI with regard to dynamic imaging (13). These include situations where a specific maneuver or position is required to elicit symptoms. Many such abnormalities are not seen with static MRI. With ultrasound, virtually any dynamic maneuver can be evaluated real time as tolerated by the patient. Examples for the shoulder include external rotation for evaluation of biceps dislocation (7), arm abduction for external impingement (3), and arm crossover for acromioclavicular joint separation (19).

Sonography has advantage over unenhanced MRI when there is a need to differentiate cystic from solid lesions. A “cystic” lesion that appears amenable to aspiration on

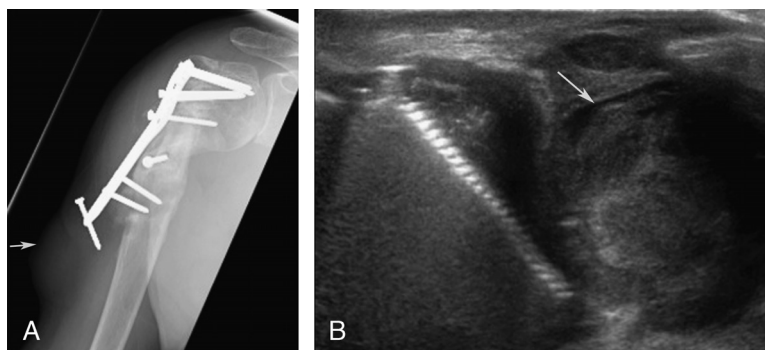


Figure 4: A. Radiograph demonstrates failure of the hardware with a soft tissue density superficial to the lowermost screw (*arrow*). B. Corresponding ultrasound shows a complex fluid collection (*arrow*) that was consistent with an abscess superficial to the screw. Note there is no sonographic artifact superficial to the screw, and thus the fluid collection is characterized.



Figure 5: A. Transverse ultrasound image shows partial tearing of the biceps tendon in the bicipital groove (arrow). B. Corresponding MRI also demonstrates the biceps tendon partial tearing. The tendon is pressed against the lesser tuberosity in both images.

unenhanced MRI often turns out to be filled with thick, complex debris or synovitis on ultrasound (18). Sonography ideally is suited to guide musculoskeletal interventions about the shoulder due to its real-time capability and ability to avoid vital structures (12).

Additional advantages of ultrasound over MRI also come into play when MRI is contraindicated absolutely or relatively. This would include patients with cardiac pacemakers and certain metal implants and patients with claustrophobia who may require sedation to complete an MR examination. There are no such contraindications to ultrasound.

Sonography can resolve finer detail than can be shown by standard clinical MRI techniques (18). Because of this higher resolution, subtle tendon tears and intratendinous fibers are seen better with ultrasound than MRI. Ultrasound also has superior contrast resolution as compared with MRI, making it ideally suited to detect tiny calcifications.

Other advantages of ultrasound over MRI for the shoulder are listed in Table 2. First, the likelihood of detecting the key abnormality and formulating a clinically relevant imaging report is greater with ultrasound than MRI because the probe can be placed directly at site of pain (18). Because many imaging findings, including rotator cuff tears, are asymptomatic (25), it is often difficult for the radiologist interpreting MRI to determine what is clinically significant. Consequently with MRI, clinically insignificant findings may be overemphasized while clinically significant findings deemphasized. Second, the source of pain may be out of the field of view when standard MRI imaging planes are produced, whereas the field of view with ultrasound is more flexible as the transducer can be placed anywhere. Third, with ultrasound, bilateral comparisons are possible. Detecting bilateral asymmetry is often useful in determining whether a questionable finding is truly abnormal. Of course, there are cases where musculoskeletal abnormalities may be bilateral.

There are applications where ultrasound and MRI are probably equal in their diagnostic performance in the appropriate clinical setting. These include evaluation of a focal tendon abnormality (rotator cuff or biceps) (Fig. 5), soft tissue fluid collection, or confirmation of a benign cyst (ganglion cyst). In these situations, the choice between MRI and ultrasound is determined likely by access to musculoskeletal ultrasound services, experience of the radiologist, referring physician preference, and patient choice (8). At least one study has shown that most patients with shoulder pain prefer ultrasound over MRI (16).

Conclusion

Both MRI and ultrasound are well suited for the evaluation of shoulder pain and should be considered complementary imaging modalities. MRI is well established as a powerful imaging modality that provides a comprehensive evaluation of the shoulder. MRI is indicated when there is question of an abnormality related to the labrum, articular cartilage, bone marrow, or deep soft tissues. Ultrasound has advantages over MRI when imaging around hardware, for detecting foreign bodies, when there is need to perform a dynamic maneuver to elicit pathology, and for guiding procedures. Ultrasound is indicated also if the patient has a pacemaker, has a non-MRI-compatible metal implant, or is claustrophobic. Ultrasound and MRI have shown similar diagnostic efficacies for evaluation of the rotator cuff. When clinical findings require rotator cuff evaluation, the choice between MRI and ultrasound is influenced by access to imaging, radiologist experience, referring physician preference, MRI contraindications, and patient choice.

The authors declare no conflict of interest and do not have any financial disclosures. All figures provided are original and have not been previously published.

References

- Balich SM, Sheley RC, Brown TR, *et al.* MR imaging of the rotator cuff tendon: interobserver agreement and analysis of interpretive errors. *Radiology*. 1997; 204:191-4.
- Boyse TD, Fessell DP, Jacobson JA, *et al.* US of soft-tissue foreign bodies and associated complications with surgical correlation. *Radiographics*. 2001; 21:1251-6.
- Bureau NJ, Beauchamp M, Cardinal É, Brassard P. Dynamic sonography evaluation of shoulder impingement syndrome. *AJR*. 2006; 187:216-20.
- 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*. 2009; 192:1701-7.
- 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*. 2003; 7:iii, 1-166.
- Failla JM, van Holsbeeck M, Vanderschueren G. Detection of a 0.5-mm-thick thorn using ultrasound: a case report. *J. Hand Surg. Am*. 1995; 20:456-7.
- Farin PU, Jaroma H, Harju A, Soimakallio S. Medial displacement of the biceps brachii tendon: evaluation with dynamic sonography during maximal external shoulder rotation. *Radiology*. 1995; 195:845-8.
- Jacobson JA. Musculoskeletal ultrasound: focused impact on MRI. *AJR*. 2009; 193:619-27.
- Jacobson JA. Musculoskeletal sonography and MR imaging. A role for both imaging methods. *Radiol. Clin. North Am*. 1999; 37:713-35.
- Jacobson JA, Lax MJ. Musculoskeletal sonography of the postoperative orthopedic patient. *Semin. Musculoskelet Radiol*. 2002; 6:67-77.

11. Jacobson JA, van Holsbeeck MT. Musculoskeletal ultrasonography. *Orthop. Clin. North Am.* 1998; 29:135–67.
12. Joines MM, Motamedi K, Seeger L, DiFiori JP. Musculoskeletal interventional ultrasound. *Semin. Musculoskelet Radiol.* 2007; 11:192–8.
13. Khoury V, Cardinal É, Bureau NJ. Musculoskeletal sonography: a dynamic tool for usual and unusual disorders. *AJR.* 2007; 188:W63–73.
14. Le Corroller T, Cohen M, Aswad R, et al. Sonography of the painful shoulder: role of the operator's experience. *Skeletal Radiol.* 2008; 37:979–86.
15. Martin-Hervas C, Romero J, Navas-Acien A, et al. Ultrasonographic and magnetic resonance images of rotator cuff lesions compared with arthroscopy or open surgery findings. *J. Shoulder Elbow Surg.* 2001; 10:410–5.
16. Middleton WD, Payne WT, Teefey SA, et al. Sonography and MRI of the shoulder: comparison of patient satisfaction. *AJR.* 2004; 183:1449–52.
17. Middleton WD, Teefey SA, Yamaguchi K. Sonography of the rotator cuff: analysis of interobserver variability. *AJR.* 2004; 183:1465–8.
18. Nazarian LN. The top 10 reasons musculoskeletal sonography is an important complement or alternative technique to MRI. *AJR.* 2008; 190:1621–6.
19. Peetrons P, Bedard JP. Acromioclavicular joint injury: enhanced technique of examination with dynamic maneuver. *J. Clin. Ultrasound.* 2007; 35:262–7.
20. Ruotolo C, Nottage WM. Surgical and nonsurgical management of rotator cuff tears. *Arthroscopy.* 2002; 18:527–31.
21. Sofka CM, Adler RS. Sonographic evaluation of shoulder arthroplasty. *AJR.* 2003; 180:1117–20.
22. Teefey SA, Hasan SA, Middleton WD, et al. Ultrasonography of the rotator cuff: a comparison of ultrasonographic and arthroscopic findings in one hundred consecutive cases. *J. Bone Joint Surg. Am.* 2000; 82:498–4.
23. Van Holsbeeck MT, Kolowich PA, Eyster WR, et al. US depiction of partial-thickness tear of the rotator cuff. *Radiology.* 1995; 197:443–6.
24. Vlychou M, Dailiana Z, Fotiadou A, et al. Symptomatic partial rotator cuff tears: diagnostic performance of ultrasound and magnetic resonance imaging with surgical correlation. *Acta. Radiol.* 2009; 50:101–5.
25. Yamaguchi K, Ditsios K, Middleton WD, et al. The demographic and morphological features of rotator cuff disease: a comparison of asymptomatic and symptomatic shoulders. *J. Bone Joint Surg. Am.* 2006; 88:1699–704.