Comparison of High-Field-Strength Versus Low-Field-Strength MRI of the Shoulder

OBJECTIVE. Previous studies have reported similar results of shoulder MRI versus arthroscopy for high-field-strength (1.5-T) and low-field-strength (0.2-T) units. We report our experience with the accuracy of high- versus low-field-strength units versus arthroscopy for detection of supraspinatus tendon tears and labral tears in the same patients.

SUBJECTS AND METHODS. Three musculoskeletal radiologists prospectively interpreted shoulder MRIs from 40 patients who had a complete shoulder MRI examination on a 0.2-T system and limited imaging on a 1.5-T unit. Proton-density axial and fat-saturated T2-weighted coronal and sagittal sequences were performed. Each radiologist interpreted the open unit images first and the high-field-strength images second. Results from 28 patients who also underwent arthroscopy were also compared with the MRI interpretations. All scans were then retrospectively reinterpreted by consensus of the three reviewers, who were unaware of the patient's name, results of previous MRI, or arthroscopy report (if any).

RESULTS. High-field-strength images altered reviewers' interpretations of low-field-strength scans for nine of 40 patients. In four patients, full-thickness supraspinatus tendon tears could be diagnosed definitively on the high-field-strength unit but not on the open unit. Three labral tears and two superior labral anteroposterior lesions could be depicted definitively on the high-field-strength unit but not on the open unit. All tears were confirmed at arthroscopy.

CONCLUSION. High-field-strength MRI units provide better spatial and contrast resolution and allow more accurate interpretations than low-field-strength units; these findings may affect clinical treatment.

Several previous studies have compared MRI of the shoulder from high-field-strength (1.5 T) versus low-field-strength (0.2–0.3 T) imaging units. Most of those previous studies indicated no significant clinical differences in interpretations of low- versus high-field-strength units. Such studies were limited in that the same patients were not imaged on both high- and low-field-strength units. Also, most of these studies were retrospective in nature [1–4].

Open low-field-strength MRI units are popular imaging tools because claustrophobic patients tolerate them better than the more confining high-field-strength units. Some obese patients fit only into open units. Most low-field-strength units also cost less to purchase and maintain than high-field-strength units. However, often the low-field-strength units do not have fat suppression, and imaging takes considerably longer. The additional imaging time increases the risk of patient motion and resultant motion artifacts.

The strength of the magnetic field is measured in gauss or tesla units (10,000 G = 1 T). In general, higher field strength improves the signal-to-noise ratio (SNR). SNR, contrast, and resolution increase almost linearly with field strength, at least up to 1.5 T. The increases allow faster scanning and lower the incidence of motion artifacts [5, 6].

Image noise can affect visualization of low-contrast lesions. The ratio of signal difference (or contrast) to noise indicates how well a lesion can be detected. Faster scanning times and thinner slices tend to reduce noise. Image noise adversely affects the reviewer's ability to detect low-contrast lesions. Noise is reduced relative to signal by increasing voxel volume. Voxel volume can be increased by increasing the field of view or increasing the slice thickness. However, higher voxel volume may cause volume-averag-
ing signal abnormalities that make lesions more difficult to detect [5, 6].

We undertook this study to determine whether imaging the same patients on both high- (1.5-T) and low-field-strength (0.2-T) units would affect MRI interpretations, and if so, whether these differences in interpretation would affect clinical treatment.

Subjects and Methods

One hundred fifty-three consecutive patients undergoing open MRI were asked if they would agree to additional limited imaging on an adjacent 1.5-T MRI unit. Those who agreed to the additional procedure were scanned on the same day as their low-field-strength scan. Most of the 113 patients who did not wish to have additional imaging were cited claustrophobia as the reason that they did not wish to have additional imaging. Patients ranged in age from 21 to 74 years (mean, 47 years).

All patients had a complete shoulder MRI examination on an open 0.2-T system (General Electric Medical Systems, Milwaukee, WI). MRI sequences on the open system were as follows: coronal T1-weighted images (TR/TE, 685/12; imaging time, 6 min 43 sec), T2-weighted images (3,350/94.5; imaging time, 7 min 21 sec), and STIR images (2,500/22; imaging time, 7 min 41 sec) with a net excitation of 4 and an 18-cm field of view. Some patients were not imaged in all sequences.

Forty patients agreed to undergo the additional MRI on the adjacent high-field-strength (1.5-T) scanner (General Electric Medical Systems). Coronal and sagittal fast spin-echo T2-weighted images (2,500/68; imaging time, 2 min 27 sec for each sequence) with a 14-cm field of view, 4-mm slice thickness with 1-mm interslice gap, and a net excitation of 2 were obtained. Patients also underwent axial fast spin-echo proton-density images (2,375/34; imaging time, 2 min 36 sec) with a 14-cm field of view, 4-mm slice thickness with a 1-mm interslice gap, and a net excitation of 2. A phased array shoulder coil was used on all patients.

Three experienced musculoskeletal radiologists prospectively reviewed the shoulder scans from the 40 patients who agreed to undergo both series of MRIs. Each radiologist interpreted the low-field-strength images first and the high-field-strength images second and determined whether any differences between low-field-strength and high-field-strength scans altered their interpretation. Twenty-eight patients also agreed to arthroscopy, and the results were compared with the prospective interpretations of the high- and low-field-strength units. All arthroscopies were performed less than 2 months after the MRI.

On prospective review, MRIs from both units were analyzed by one radiologist for the presence or absence of full-thickness supraspinatus tendon tears, superior labral anteroposterior (SLAP) tears, and anterior or posterior labral tears. Full-thickness supraspinatus tendon tears were defined as areas of fluid signal traversing the entire thickness of the supraspinatus tendon on T2-weighted or STIR images, or as supraspinatus tendon retraction. SLAP tears were defined as areas of high signal on T2-weighted or STIR images in the superior labrum or contour irregularities of the superior labrum. Anterior or posterior labral tears were defined as areas of abnormal increased signal on T2 or STIR images or contour irregularities of the anterior or posterior labrum.

All 40 MRIs were retrospectively reinterpreted by consensus of the three radiologists, who were unaware of patient’s name, results of previous MRIs, or arthroscopy report (if any). The reinterpretations were done at one sitting, with high- and low-field-strength images from the same patient presented out of order in a random fashion so as not to bias the reviewers.

Results

Forty patients were scanned on both high- (1.5-T) and low-field-strength (0.2-T) units. For 31 patients, prospective reviewer interpretations were the same for both units. Arthroscopic results were available for 19 patients. Sixteen of the 19 showed full-thickness supraspinatus tears on both low- and high-field-strength prospective MRI interpretations. Two patients had anterior labral tears and one had a SLAP lesion on both high- and low-field-strength prospective MRI interpretations. All MRI reviews were confirmed arthroscopically. Partial-thickness tears and tendinosis were not included in the results because these findings did not affect surgical treatment.

Fig. 1.—47-year-old man with shoulder pain.
A, T1-weighted axial 0.2-T image (TR/TE, 685/12) shows no abnormality in posterior labrum (arrow).
B, STIR axial 0.2-T image (2,500/22; inversion time, 75 msec) shows no definite abnormality in posterior labrum. Subtle area of increased signal (arrow) may be visible in posterior labrum.
C, T2-weighted axial 1.5-T image (2,500/68) shows abnormal signal and irregularity in posterior labrum confirmed at arthroscopy to be posterior labral tear (arrow).
Retrospective blinded consensus interpretations by the three radiologists did not differ from prospective MRI reviews.

High-field-strength images altered prospective interpretations in nine patients. Two anterior labral tears, a posterior labral tear, and two SLAP lesions could be definitively seen on the high-field-strength unit but not on the low-field-strength unit (Figs. 1–3). The anterior labral tears were in the anteroinferior portion of the labrum and both were detached. The posterior labral tear was not detached. These labral tears were confirmed at arthroscopy.

In four patients, it was difficult to determine on the open MRI whether a partial- or full-thickness supraspinatus tendon tear was present. The high-field-strength MRI unit allowed definitive interpretation of a full-thickness tear and a more accurate delineation of the degree of tendon retraction. Three of these full-thickness supraspinatus tendon tears were small tears without any appreciable degree of tendon retraction (Fig. 4). One of the four full-thickness supraspinatus tendon tears was retracted by 3 cm (Fig. 5). Fibrosis in the area of the tear prevented it from showing high signal and made it difficult to see the free edge of the retracted supraspinatus tendon on the images obtained on the low-field-strength unit. These full-thickness tears were all confirmed at arthroscopy.

**Discussion**

The high-field-strength MRI altered reviewer interpretation in nine of 40 cases. All the high-field-strength interpretations in those cases were confirmed at arthroscopy. Our findings differ from those of most previous studies comparing high- and low-field-strength MRI interpretations. Shellock et al. [1] compared interpretations in 47 patients who underwent MRI in a 0.2-T extremity MRI system with findings at arthroscopy. They found that the sensitivity, specificity, and predictive values for MRI of rotator cuff and labral tears compared favorably with those values published in the literature for mid- and high-field-strength MRI systems. Their study differs from ours in that they did not scan the same patients on both high- and low-field-strength units and compare the results. They compared the results of one set of patients on a low-field-strength unit with results from other sets of patient results previously published in the literature.

Tung et al. [2] compared high-field-strength versus low-field-strength MRI for the diagnosis of SLAP lesions. They found high-field-
The study by Tung et al. compared results from one set of patients scanned on a low-field-strength unit with those from another set of patients scanned on a high-field-strength unit. Other studies have compared low- and high-field-strength units with two sets of patients. These other studies found no significant differences in MRI interpretation between the two sets [3, 4].

Our study differs from previous studies in that it is prospective. Also, all patients in the study underwent MRI on both high- and low-field-strength units. The low-field-strength interpretations were provided first and the high-field-strength interpretations second. The radiologists then determined whether their interpretations had changed.

A difference in interpretation does not necessarily affect clinical treatment. In the nine instances of differences in reviewer interpretation between the high- and low-field-strength units, the orthopedic surgeon involved indicated that the high-field-strength interpretations did alter clinical treatment because surgery was performed to address the findings shown on the high-field-strength unit. All nine of these high-field-strength interpretations were confirmed arthroscopically.

High-field-strength units provide more signal to noise than low-field-strength units. Also, scans are performed much more quickly. Therefore, patient motion is less on the high-field-strength units than on low-field-strength units [5, 6].

Image quality is based on contrast resolution and noise. Noise is caused by random motion of electrons produced primarily by the coil and the patient's body. Increasing the time duration for signal acquisition reduces image noise. All things being equal, the

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**Fig. 4.**—53-year-old man with shoulder pain. A and B, STIR coronal (A) and sagittal (B) 0.2-T images (TR/TE, 2,500/22; inversion time, 75 msec) show abnormal signal (arrow) in distal supraspinatus tendon but no full-thickness tear. C, T2-weighted coronal 1.5-T image (2,500/68) shows small full-thickness supraspinatus tendon tear (arrow), that was confirmed at arthroscopy.

**Fig. 5.**—68-year-old man with shoulder pain. A, T2-weighted coronal 0.2-T image (TR/TE, 3,350/94.5) shows attenuation of supraspinatus tendon (arrow) but no definite full-thickness tear. B and C, T2-weighted coronal (B) and sagittal (C) images show full-thickness supraspinatus tendon tears, one with retraction (arrow, B) and the other (arrow, C) confirmed at arthroscopy.
strength of signal from a voxel is proportional to the voxel volume. The SNR is proportional to the voxel volume times the square root of the signal acquisition time. Any technique that increases signal acquisition time will increase the SNR. Any technique that decreases voxel volume in an attempt to improve spatial resolution will decrease the SNR. The spatial resolution reflects the sharpness of the image [5, 6].

High-field-strength units inherently provide a better SNR than low-field-strength units. They allow faster imaging and thinner slice thicknesses. The decrease in slice thickness (voxel volume) allows better spatial resolution [5, 6].

Thinner slice thickness (4 vs 5 mm on the low-field-strength unit) and a smaller field of view (14 cm on high-field-strength unit vs 20 cm on the low-field-strength unit) were used for the high-field-strength unit images. This most likely resulted in better visualization of subtle signal abnormalities, allowing better resolution of small full-thickness tears, supraspinatus tears, small labral tears, and subtle SLAP lesions. These small tears did not resolve as well on the low-field-strength units because the larger slice thickness needed to maintain adequate SNR required more volume averaging.

A potential limitation of this study is that all musculoskeletal radiologists were from the same institution and performed consensus interpretation on retrospective review. These individuals may interpret MRIs more uniformly than individuals from different institutions.

In conclusion, the superior spatial and contrast resolution of the high-field-strength units may result in more accurate interpretation of full-thickness supraspinatus tendon tears and labral tears in some patients than would be possible with low-field-strength units. The changes in reviewer interpretation may have an effect on clinical treatment.

References