Ultrasonography of the Rotator Cuff : A Comparison of Ultrasonographic and Arthroscopic Findings in One Hundred Consecutive Cases

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A Comparison of Ultrasonographic and Arthroscopic Findings in One Hundred Consecutive Cases*

BY SHARLENE A. TEEFEY, M.D.†, S. ASHFAQ HASAN, M.D.†, WILLIAM D. MIDDLETON, M.D.†, MIHIR PATEL, M.D.†, RICK W. WRIGHT, M.D.†, AND KEN YAMAGUCHI, M.D.†

Investigation performed at the Mallinckrodt Institute of Radiology and the Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri

Abstract

Background: **There has been limited acceptance of shoulder ultrasonography by orthopaedic surgeons in the United States. The purpose of this retrospective study was to determine the diagnostic performance of high-resolution ultrasonography compared with arthroscopic examination for the detection and characterization of rotator cuff tears.**

Methods: **One hundred consecutive shoulders in ninety-eight patients with shoulder pain who had undergone preoperative ultrasonography and subsequent arthroscopy were identified. The arthroscopic diagnosis was a full-thickness rotator cuff tear in sixty-five shoulders, a partial-thickness tear in fifteen, rotator cuff tendinitis in twelve, frozen shoulder in four, arthrosis of the acromioclavicular joint in two, and a superior labral tear and calcific bursitis in one shoulder each. All ultrasonographic reports were reviewed for the presence or absence of a rotator cuff tear and a biceps tendon rupture or dislocation. All arthroscopic examinations were performed according to a standardized operative procedure. The size and extent of the tear and the status of the biceps tendon were recorded for all shoulders. The findings on ultrasonography and arthroscopy then were compared for each parameter.**

Results: **Ultrasonography correctly identified all sixty-five full-thickness rotator cuff tears (a sensitivity of 100 percent). There were seventeen true-negative and three false-positive ultrasonograms (a specificity of 85 percent). The overall accuracy was 96 percent. The size of the tear on transverse measurement was correctly predicted in 86 percent of the shoulders with a full-thickness tear. Ultrasonography detected a tear in ten of fifteen shoulders with a partial-thickness tear that was diagnosed on arthroscopy. Five of six dislocations and seven of eleven ruptures of the biceps tendon were identified correctly.**

Conclusions: **Ultrasonography was highly accurate for detecting full-thickness rotator cuff tears, characterizing their extent, and visualizing dislocations of the biceps tendon. It was less sensitive for detecting partial-thickness rotator cuff tears and ruptures of the biceps tendon.**

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†Mallinckrodt Institute of Radiology (S. A. T. and W. D. M.) and Department of Orthopaedic Surgery (S. A. H., M. P., R. W. W., and K. Y.), Washington University School of Medicine, 510 South Kingshighway, Box 8131, St. Louis, Missouri 63110.

The use of high-resolution ultrasonography in North America for the detection of rotator cuff tears has achieved only limited acceptance by orthopaedic surgeons compared with other modalities such as magnetic resonance imaging. Uncertainty about the accuracy of this modality may have contributed to its low utilization rate. Although initial studies, published in the mid-1980s, that compared ultrasonographic and surgical findings showed a high rate of accuracy (92 to 94 percent in series of fifty-one and forty-seven patients[5,7]) for the detection of rotator cuff tears, later studies showed somewhat lower rates (60 to 84 percent in series of thirty-eight, ten, and forty-nine patients[1,3,9]). Additionally, only a few studies have compared the accuracy of ultrasonography with that of arthroscopy for determining the presence or absence of rotator cuff tears[2,8,12,13] and fewer have correlated the tear size with the surgical findings[2,13]. Brenneke and Morgan, in a study of sixty-one patients, found that ultrasonography had a sensitivity of 95 percent and a specificity of 93 percent for the detection of full-thickness tears[2]. They also found that it accurately predicted the size of full-thickness tears in 89 percent of patients who had a tear that was greater than four centimeters, in 43 percent of those who had a tear that was two to four centimeters, and in 70 percent of those who had a tear that was less than two centimeters. Wiener and Seitz, in a study of 225 patients, demonstrated that ultrasonography had a sensitivity of 95 percent and a specificity of 94 percent for the detection of full-thickness tears and a sensitivity of 91 percent and a specificity of 94 percent for predicting the size of the tear[13].

The purpose of the current study was to compare the diagnostic performance of ultrasonography with that of arthroscopic surgery to determine its accuracy for detecting rotator cuff tears and biceps tendon pathology.

Materials and Methods

The study comprised 100 shoulders in ninety-eight consecutive patients with shoulder pain who had under-

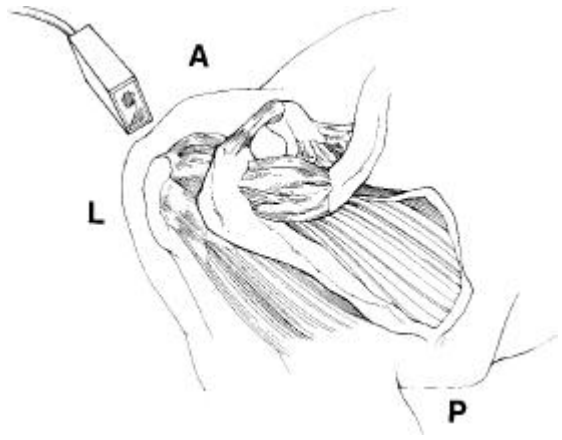

FIG. 1-A

Drawing of a left shoulder, viewed from above with the arm in extension, showing the transducer oriented in a plane parallel to the longitudinal axis of the rotator cuff. A = anterior, L = lateral, and P = posterior.

gone standardized preoperative ultrasonography and subsequent arthroscopy between January 1996 and September 1997. The interval of time between the ultrasonographic and the arthroscopic examination ranged from one to 417 days (mean, sixty days). There were fifty-four female patients and forty-four male patients, and their ages ranged from fourteen to eighty-two years (mean age, fifty-six years).

The primary arthroscopic or final clinical diagnosis was a full-thickness tear of the rotator cuff in sixty-five shoulders, a partial-thickness tear in fifteen, rotator cuff tendinitis in twelve, frozen shoulder in four, arthrosis of the acromioclavicular joint in two, and a superior labral tear and calcific bursitis in one shoulder each. Two patients with a full-thickness tear had a large partial-thickness component.

In general, the indications for the surgery and the arthroscopic examination included shoulder pain of more than six months' duration and a lack of a response to nonoperative treatment including physical therapy, nonsteroidal anti-inflammatory medications, and at least one cortisone injection. For the patients with a full-thickness tear, the indications for the operation included severe pain of more than three months' duration despite the nonoperative measures just mentioned. Patients with a full-thickness tear who had a recent loss of shoulder elevation or a recent injury (sustained less than three months before the time of presentation) were offered the option of an operation at earlier than three months.

Ultrasonographic Technique

All ultrasonograms were obtained in real time with use of an ATL HDI 3000 scanner (Advanced Technologies Laboratories, Bothell, Washington) or a Siemens Elegra scanner (Siemens Medical Systems, Issaquah, Washington) and a variable high-frequency linear-array transducer (7.5 to ten megahertz). All patients had standardized bilateral ultrasonography of the shoulder, performed by one of two radiologists who were very experienced with the technique and who had conducted more than 2500 examinations during a ten-year period.

The ultrasonographic examination was performed with the patient seated on a stool and the radiologist standing behind the patient. First, the biceps tendon was examined in the transverse plane from the level of the acromion inferiorly to the point where the tendon merged with the biceps muscle. The transducer then was rotated 90 degrees in order to examine the tendon longitudinally. Next, images of the subscapularis tendon were made with the patient's arm externally rotated; the transducer was placed in a transverse anatomical orientation at the level of the lesser tuberosity and was moved medially.

Images of the supraspinatus tendon were made with the shoulder extended, the elbow flexed, and the hand placed on the iliac wing. This position was necessary in order to expose as much of the supraspinatus tendon as possible from under the acromion. The transducer was oriented parallel to the tendon (approximately 45 degrees between the coronal and sagittal planes) in order to visualize the fibers in a longitudinal plane (Figs. 1-A and 1-B), and it was moved anteriorly to posteriorly in order to visualize the supraspinatus and infraspinatus tendons. The transducer was rotated 90 degrees in order to examine the tendons in the transverse plane (Figs. 2-A and 2-B).

Ultrasonographic Criteria

A finding of a full-thickness rotator cuff tear was recorded when the rotator cuff could not be visualized because of complete avulsion and retraction under the acromion or when there was a focal defect in the rotator cuff created by a variable degree of retraction of the torn tendon ends. In the latter case, either joint fluid or thickened bursal tissue and the deep surface of the del-

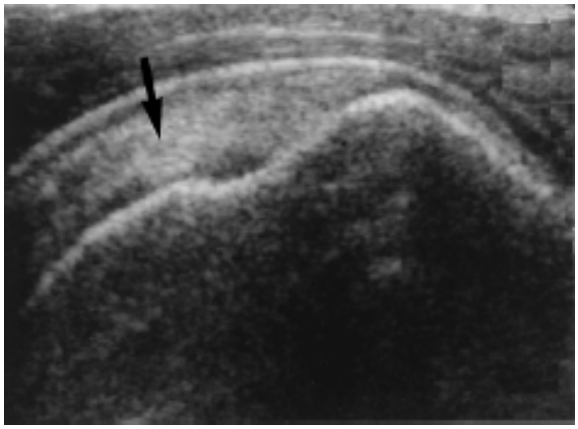

FIG. 1-B

Corresponding ultrasonographic image showing the rotator cuff (arrow) in the longitudinal plane.

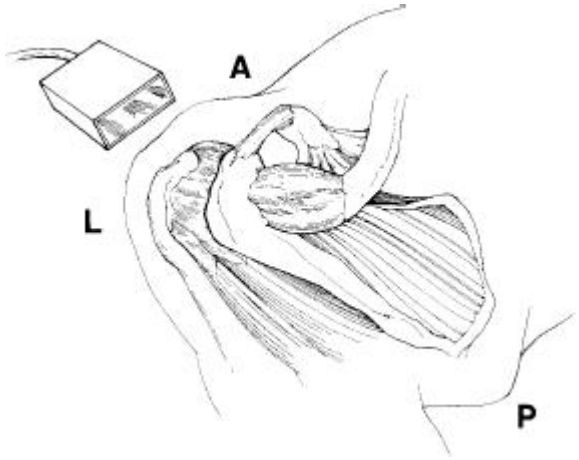

FIG. 2-A

Drawing of a left shoulder, viewed from above with the arm in extension, showing the transducer oriented in a plane perpendicular to the longitudinal axis of the rotator cuff. A = anterior, L = lateral, and P = posterior.

toid muscle occupied the defect created by the tear. If no tear was visualized, the deltoid muscle was compressed against the cuff with the transducer in an attempt to separate the torn tendon ends at the site of a nonretracted tear.

A finding of a partial-thickness tear was recorded when there was minimal flattening of the bursal side of the rotator cuff (a bursal-side partial-thickness tear) or a distinct hypoechoic or mixed hyperechoic and hypoechoic defect visualized in both the longitudinal and the transverse plane at the deep articular side of the rotator cuff (an articular-side partial-thickness tear).

The extent of the rotator cuff tear was determined with transverse measurements. According to empirical guidelines instituted prior to the inception of this study, if the tear extended posteriorly 1.5 centimeters or less from the intra-articular portion of the biceps tendon it was recorded as involving only the supraspinatus tendon, whereas if it extended more than 1.5 to 3.0 centimeters it was recorded as involving both the supraspinatus and the infraspinatus tendon. The teres minor tendon was not evaluated when the extent of the tear was determined.

A finding of a rupture of the biceps tendon was recorded when the tendon was not identified within or medial to the intertubercular sulcus. Dislocation of the biceps tendon was recorded when the tendon was anterior or medial to the lesser tuberosity.

Surgical Technique and Criteria

All arthroscopic examinations and operative procedures were performed by a single orthopaedic surgeon who recorded all findings in a standardized manner. The presence or absence of a rotator cuff tear and the size and extent of the tear, when present, were recorded. Specifically, the presence or absence of a full-thickness tear or of a bursal or articular-side partial-thickness tear and the width (perpendicular to the long axis of the cuff fibers) of any tear that was found were recorded. The biceps tendon was examined arthroscopically for dislocation or rupture. Representative arthroscopic images were made of all tears and other pathological findings, such as abnormalities of the biceps tendon.

In shoulders in which a partial-thickness tear was present or the arthroscopic findings were discrepant from those recorded on ultrasonography, or both, a tagging suture (number-1 PDS [polydioxanone]) was placed, from the bursal side without a knot, through the suspected area of the rotator cuff to guide arthroscopic bursal imaging. In shoulders in which a full-thickness tear was recorded on ultrasonography but was not visualized on arthroscopy, an extensive partial-thickness tear was present. In these shoulders, a mini-open deltoid split (a three to four-centimeter skin incision with approximately a three-centimeter deltoid split without any takedown of the deltoid origin) was performed to directly visualize the involved area of the rotator cuff and to verify the arthroscopic findings. Additionally, as all full-thickness tears were repaired through a mini-open deltoid-splitting approach, the size and extent of the tear were determined by direct visualization. If a partial-thickness tear was recorded on ultrasonography but was not seen on arthroscopy, a mini-open deltoid split was not performed.

Data Analysis

The ultrasonographic and arthroscopic findings were correlated with regard to the presence or absence of a full or partial-thickness rotator cuff tear, the size and extent of the tear, and the presence or absence of a dislocation or rupture of the biceps tendon. When there was disagreement between the findings, representative arthroscopic and ultrasonographic images were reevalu-

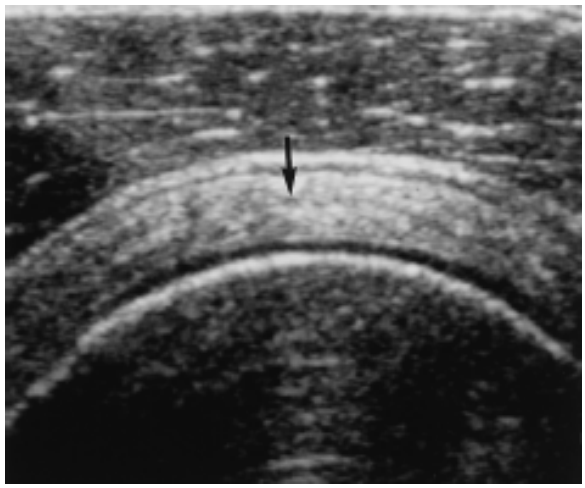

FIG. 2-B

Corresponding ultrasonographic image showing the rotator cuff (arrow) in the transverse plane.

TABLE I
FULL-THICKNESS ROTATOR CUFF TEARS: ULTRASONOGRAPHIC VERSUS ARTHROSCOPIC FINDINGS*

	Arthroscopy		
	Positive	Negative	Total
Ultrasonography			
Positive	65	3	68
Negative	0	17	17
Total	65	20	85

*The values are given as the numbers of shoulders. When true-positive indicated a full-thickness tear and true-negative, no tear, ultrasonography had a sensitivity of 100 percent (sixty-five of sixty-five), a specificity of 85 percent (seventeen of twenty), a positive predictive value of 96 percent (sixty-five of sixty-eight), a negative predictive value of 100 percent (seventeen of seventeen), and an accuracy of 96 percent (eighty-two of eighty-five).

ated jointly to explain the discrepancy.

Only the full-thickness tears were analyzed with regard to their size and extent. The subscapularis was classified only as intact or torn. Two of the sixty-five shoulders with a full-thickness tear were excluded from the analysis; one shoulder had a very limited range of motion and indeterminate findings regarding the extent of the tear on ultrasonography, and the other shoulder had had the arthroscopic examination one year after the ultrasonographic study.

Results

Detection of Rotator Cuff Tears

Ultrasonography correctly identified all sixty-five full-thickness rotator cuff tears that were diagnosed on arthroscopy (Figs. 3-A and 3-B, and Table I). There were no false-negative studies. Ultrasonography incorrectly identified a full-thickness rotator cuff tear in three shoulders that were found to have a partial-thickness tear on arthroscopy; one of the three tears was extensive (more than 50 percent of the cuff thickness) and involved the entire supraspinatus tendon.

Ultrasonography correctly identified seven of fifteen partial-thickness rotator cuff tears that were diagnosed on arthroscopy (Figs. 4-A and 4-B, and Table II). In three additional shoulders, it identified a full-thickness rather than a partial-thickness tear. Because a tear was identified, these studies were considered to be true-positive. There were five false-negative studies. Ultrasonographic visualization of the rotator cuff was limited by a decreased range of motion in two of these shoulders, and arthroscopy showed only mild fraying of the supraspinatus tendon in a third. There were three false-positive ultrasonograms, one of which showed an ill defined hypoechoic region, suggestive of a partial tear, on the deep capsular side of the cuff near its insertion. Another of the false-positive studies showed subtle flattening of the bursal side of the supraspinatus tendon. Ultrasonography correctly predicted the absence of a tear in seventeen of twenty shoulders that had no evidence of a tear on arthroscopy.

In six shoulders for which the arthroscopic findings were discrepant from those recorded on ultrasonography, a tagging suture was placed through the suspicious area of the rotator cuff to guide arthroscopic bursal imaging. In three of these shoulders, ultrasonography revealed a full-thickness tear but a partial-thickness tear was detected on arthroscopy. In the other three shoulders, a partial-thickness tear was recorded on ultrasonography but the cuff was normal on arthroscopy.

Size and Extent of the Tears

Of the sixty-three full-thickness rotator cuff tears that were analyzed for these parameters, twenty-six were

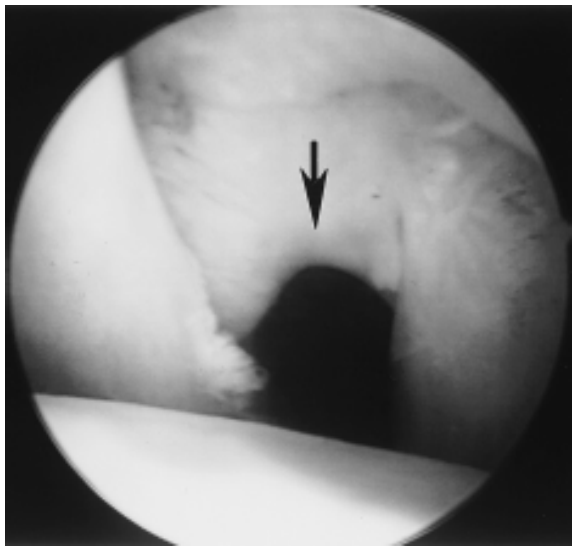

FIG. 3-A

Arthroscopic image showing a small full-thickness tear of the left supraspinatus tendon (arrow).

FIG. 3-B

Corresponding ultrasonographic image showing the small tendon tear. Fluid separates the torn tendon ends (arrow). The image is oriented in a plane perpendicular to the longitudinal axis of the tendon. The biceps tendon is to the left of the tear (arrowhead).

found on arthroscopy to involve only the supraspinatus tendon and to be less than 1.5 centimeters wide, and thirty-seven involved both the supraspinatus and the infraspinatus and were more than 1.5 centimeters wide. In addition, seven shoulders had a tear of the subscapularis tendon. Transverse measurement with ultrasonography correctly predicted the extent of the tear in twenty-one (81 percent) of the twenty-six shoulders with an isolated tear of the supraspinatus tendon. In three shoulders, ultrasonography overestimated the width of the tear by 0.5 centimeter or less and in two, by 1.1 and 1.3 centimeters. In the latter two shoulders, arthroscopy confirmed the presence of a full-thickness tear of the supraspinatus but also showed an extensive partial-thickness tear (more than 50 percent of the cuff thickness) extending into the infraspinatus tendon, which had been interpreted as a full-thickness tear on ultrasonography.

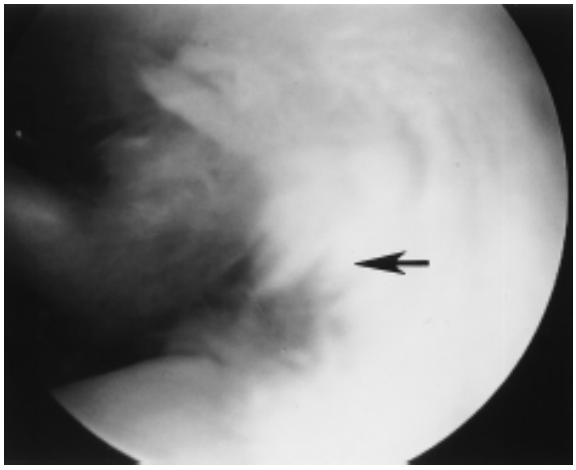

FIG. 4-A

Arthroscopic image showing a small partial-thickness tear of the right supraspinatus tendon (arrow).

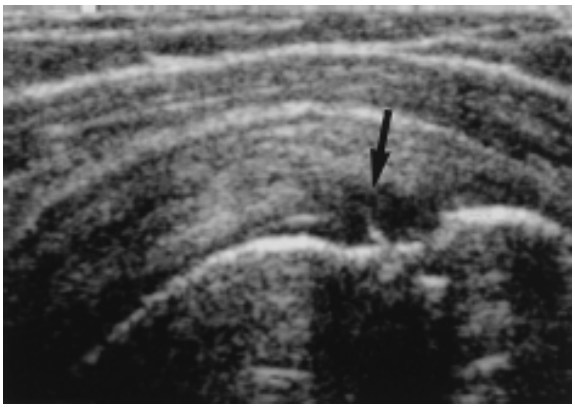

FIG. 4-B

Corresponding ultrasonographic image showing the small hypoechoic tendon tear, located on the deep capsular side of the cuff (arrow). The image is oriented in a plane parallel to the longitudinal axis of the tendon.

TABLE II

PARTIAL-THICKNESS ROTATOR CUFF TEARS: ULTRASONOGRAPHIC VERSUS ARTHROSCOPIC FINDINGS*

	Arthroscopy		
	Positive	Negative	Total
Ultrasonography			
Positive	10	3	13
Negative	5	17	22
Total	15	20	35

*The values are given as the number of shoulders. When true-positive indicated a partial-thickness tear and true-negative, no tear, ultrasonography had a sensitivity of 67 percent (ten of fifteen), a specificity of 85 percent (seventeen of twenty), a positive predictive value of 77 percent (ten of thirteen), a negative predictive value of 77 percent (seventeen of twenty-two), and an accuracy of 77 percent (twenty-seven of thirty-five).

Transverse measurement with ultrasonography correctly predicted the extent of the tear in thirty-three (89 percent) of the thirty-seven shoulders that had a combined tear of the supraspinatus and infraspinatus tendons. In the four remaining shoulders, ultrasonography underestimated the extension of the tear into the infraspinatus tendon by one to 1.5 centimeters. In three of these shoulders, arthroscopy showed that the infraspinatus component was a midsubstance extension of the tear medial to the supraspinatus portion of the tear. Ultrasonography correctly identified six of the seven tears of the subscapularis tendon. Overall, ultrasonography correctly predicted the size and extent of the tear in 86 percent of the shoulders with a full-thickness tear.

Five of the thirty-seven shoulders had a massive tear with retraction of the torn tendon underneath the acromion. The edge of the torn tendon could not be visualized at the time of the ultrasonographic study.

Dislocation of the Biceps Tendon

Ultrasonography correctly identified five of six dislocations of the biceps tendon that were diagnosed on arthroscopy. The one false-negative study, which showed an absence of the biceps tendon, was interpreted as demonstrating a rupture rather than a dislocation. There were ninety-four true-negative ultrasonograms and no false-positive ultrasonograms.

Rupture of the Biceps Tendon

Ultrasonography correctly identified seven of eleven ruptures of the biceps tendon that were diagnosed on arthroscopy. There were four false-negative studies. Two of the false-negative ultrasonograms showed the normal echogenic fibrillar pattern of the tendon within the groove. There was one false-positive ultrasonogram, and there were eighty-eight true-negative ultrasonograms.

Discussion

High-resolution shoulder ultrasonography has not been widely utilized by orthopaedic surgeons to diagnose and characterize rotator cuff and biceps tendon pathol-

ogy. This limited acceptance may be due in part to the paucity of shoulder ultrasonographic studies in the orthopaedic literature compared with magnetic resonance imaging studies, the frequent lack of local radiological expertise, and difficulty in recognizing the relevant anatomy and pathology on hard-copy ultrasonographic images. In addition, wide ranges of sensitivity (57 to 100 percent) and specificity (50 to 100 percent) have been reported, in series ranging from ten to 225 patients, for the ultrasonographic detection of rotator cuff tears, causing further uncertainty about the true accuracy of this modality[1-3,5,7-9,12,13]. Investigators who reported poor results for the diagnosis of rotator cuff tears used ultrasonographic criteria that either are no longer accepted or have been refined, employed a scanning technique that has since been modified to improve visualization of the cuff, and used older equipment and transducers with a lower frequency than is currently available[1,3,8,9].

In the present study, the accuracy of shoulder ultrasonography was reinvestigated in the context of modern refinements in the scanning technique, improvements in the resolution capabilities of the equipment, and clarification of the criteria for diagnosing a rotator cuff tear. In contrast to many of the earlier studies, in which the findings on ultrasonography were correlated with those on arthrography or open surgery, we compared the findings on ultrasonography with those on arthroscopy, which is a procedure with several potential advantages. Magnified arthroscopic images can provide accurate intra-articular and bursal visualization of the rotator cuff and, in contrast to arthrography, can delineate partial-thickness and midsubstance tears as well as intra-articular pathology of the biceps tendon.

We found that ultrasonography was highly accurate for detecting full-thickness rotator cuff tears and for characterizing their extent in the transverse plane. It led to a misdiagnosis of a full-thickness tear in only three shoulders, all of which had a partial-thickness tear on arthroscopy, with one of the tears involving more than 50 percent of the cuff substance. Our sensitivity rate of 100 percent and our specificity rate of 85 percent compare favorably not only with the rates reported in recent previous studies on ultrasonography (in which sensitivity or specificity, or both, has been as high as 95 percent[12,13]) but also with those reported in numerous magnetic resonance imaging studies[6,8,10,11].

Only a few studies have evaluated the use of ultrasonography for determining the size and extent of the tear[2,13]. Brenneke and Morgan reported that ultrasonography was accurate for predicting the size of large tears but less so for moderate and small tears[2]. We found that ultrasonography was very accurate in predicting the extent of any tear in the transverse plane. Our findings substantiate those reported by Wiener and Seitz[13]. Two of the shoulders in which we overestimated the extent of the tear by more than one centimeter had a full-thickness tear with an extensive partial-thickness component on arthroscopy. The partial-thickness component was misinterpreted as a full-thickness tear. In both of these shoulders, a focal defect was produced by compression of the deltoid muscle against the rotator cuff with the transducer, an integral part of our examination. Like full-thickness tears, partial-thickness tears involving more than 50 percent of the cuff substance appear to demonstrate a focal defect (a criterion used to define a full-thickness tear) when the deltoid muscle is compressed into the tear. While this maneuver increased the sensitivity of ultrasonography for detecting small, nonretracted, full-thickness tears, it lowered the specificity; ultrasonography may not be able to differentiate extensive partial-thickness tears from full-thickness tears.

In three shoulders in which ultrasonography underestimated the extent of the tear, arthroscopy showed a medial midsubstance extension of the supraspinatus tear into the infraspinatus tendon. The midsubstance component of the tear was not detected when we viewed only the more lateral aspect of the rotator cuff near its insertion, which demonstrates the importance of proper positioning of the arm to visualize the rotator cuff not only at its insertion but more medially.

Our ability to detect partial-thickness rotator cuff tears with ultrasonography was limited; however, two of the five shoulders that had a false-negative study had a decreased range of motion (the patient was unable to externally rotate and extend the shoulder past the level of the buttock) that prevented a thorough evaluation of the cuff, and in a third the partial-thickness tear that was identified on arthroscopy consisted only of mild fraying of the supraspinatus tendon, which may not be detectable with ultrasonography. While Brenneke and Morgan also reported a low sensitivity for the detection of partial-thickness tears[2], two other recent studies demonstrated a sensitivity of more than 90 percent[12,13].

Biceps tendon abnormalities frequently are associated with rotator cuff tears. In the current study, the prevalence of rupture of the biceps tendon was 11 percent and that of dislocation was 6 percent. The dislocations, whether anterior or medial to the lesser tuberosity, were recognized easily on ultrasonography; we correctly diagnosed five of the six dislocations. On the other hand, we identified only seven of the eleven biceps tendon ruptures. Adhesion of a ruptured biceps tendon at the articular entrance to the groove was the most likely cause of a false-negative ultrasonogram. Two of the false-negative ultrasonographic studies showed the normal echogenic fibrillar pattern of the tendon within the groove, creating the false impression of an intact tendon.

Our study was limited by its retrospective design; however, when the operative and ultrasonographic findings were in disagreement, representative ultrasonographic hard-copy and arthroscopic images were reviewed jointly to explain the discrepancy. Additionally, prior to the inception of this study, standardized criteria for determining the presence, location, and ex-

tent of a rotator cuff tear in the transverse plane had been established, and the statistical analysis was based on the original interpretation of the ultrasonographic study rather than on a retrospective review of the images.

Although diagnostic arthroscopy was performed in an unblinded fashion, the surgeon's knowledge of the ultrasonographic results prior to the operation was advantageous to the patient as it led to a more focused evaluation of the rotator cuff, particularly when the arthroscopic findings did not correlate with the ultrasonographic report. In all shoulders for which a discrepant ultrasonographic finding was reported, the area in question was tagged with a suture intraoperatively to allow focused intra-articular and bursal-side viewing of the cuff.

Patients with a normal ultrasonogram who had resolution of the symptoms did not have arthroscopy and were not included in the study. Hence, it is possible that the actual number of false-negative studies may have been greater than what our study showed. On the other hand, patients with normal ultrasonograms but persistent symptoms frequently had arthroscopy and thus were included in the study. Since patients with persistent symptoms are more likely to have a tear than patients in whom the symptoms have resolved, it is unlikely that the sensitivity would have decreased markedly had we included all patients with normal ultrasonograms.

We found that ultrasonography was a highly accurate and reliable technique for detecting full-thickness rotator cuff tears and biceps tendon dislocations in painful shoulders. The high accuracy is in part attributable to improved image resolution, optimization of the scanning technique, and reliance on well defined criteria. However, more than with almost any other imaging modality that is employed to evaluate the shoulder, the success of an ultrasonographic examination depends heavily on the experience of the operator.

In summary, our findings indicate that shoulder ultrasonography can be a valuable noninvasive procedure for imaging of the rotator cuff. Not only is it comparable with magnetic resonance imaging in terms of accuracy for detecting full-thickness tears; it provides bilateral information, is better tolerated, allows patient viewing of real-time information, and is less expensive. Improvements in image resolution have allowed for more intuitive anatomical and correlative pathological interpretation of the hard-copy images by orthopaedic surgeons. Increased awareness of the important role that ultrasonography can play in the diagnosis of rotator cuff pathology may foster acceptance and increase the availability of this imaging modality to the orthopaedic community.

References

1. **Brandt, T. D.; Cardone, B. W.; Grant, T. H.; Post, M.;** and **Weiss, C. A.:** Rotator cuff sonography: a reassessment. *Radiology,* 173: 323-327, 1989.
2. **Brenneke, S. L.,** and **Morgan, C. J.:** Evaluation of ultrasonography as a diagnostic technique in the assessment of rotator cuff tendon tears. *Am. J. Sports Med.,* 20: 287-289, 1992.
3. **Burk, D. L., Jr.; Karasick, D.; Kurtz, A. B.; Mitchell, D. G.; Rifkin, M. D.; Miller, C. L.; Levy, D. W.; Fenlin, J. M.;** and **Bartolozzi, A. R.:** Rotator cuff tears: prospective comparison of MR imaging with arthrography, sonography, and surgery. *AJR: Am. J. Roentgenol.,* 153: 87-92, 1989.
4. **Clark, J. M.,** and **Harryman, D. T., II:** Tendons, ligaments, and capsule of the rotator cuff. Gross and microscopic anatomy. *J. Bone and Joint Surg.,* 74-A: 713-725, June 1992.
5. **Hodler, J.; Fretz, C. J.; Terrier, F.;** and **Gerber, C.:** Rotator cuff tears: correlation of sonographic and surgical findings. *Radiology,* 169: 791-794, 1988.
6. **Iannotti, J. P.; Zlatkin, M. B.; Esterhai, J. L.; Kressel, H. Y.; Dalinka, M. K.;** and **Spindler, K. P.:** Magnetic resonance imaging of the shoulder. Sensitivity, specificity, and predictive value. *J. Bone and Joint Surg.,* 73-A: 17-29, Jan. 1991.
7. **Mack, L. A.; Matsen, F. A., III; Kilcoyne, R. F.; Davies, P. K.;** and **Sickler, M. E.:** US evaluation of the rotator cuff. *Radiology,* 157: 205-209, 1985.
8. **Nelson, M. C.; Leather, G. P.; Nirschl, R. P.; Pettrone, F. A.;** and **Freedman, M. T.:** Evaluation of the painful shoulder. A prospective comparison of magnetic resonance imaging, computerized tomographic arthrography, ultrasonography, and operative findings. *J. Bone and Joint Surg.,* 73-A: 707-716, June 1991.
9. **Paavolainen, P.,** and **Ahovuo, J.:** Ultrasonography and arthrography in the diagnosis of tears of the rotator cuff. *J. Bone and Joint Surg.,* 76-A: 335-340, March 1994.
10. **Quinn, S. F.; Sheley, R. C.; Demlow, T. A.;** and **Szumowski, J.:** Rotator cuff tendon tears: evaluation with fat-suppressed MR imaging with arthroscopic correlation in 100 patients. *Radiology,* 195: 497-500, 1995.
11. **Rafii, M.; Firooznia, H.; Sherman, O.; Minkoff, J.; Weinreb, J.; Golimbu, C.; Gidumal, R.; Schinella, R.;** and **Zaslav, K.:** Rotator cuff lesions: signal patterns at MR imaging. *Radiology,* 177: 817-823, 1990.
12. **Van Holsbeeck, M. T.; Kolowich, P. A.; Eyler, W. R.; Craig, J. G.; Shirazi, K. K.; Habra, G. K.; Vanderschueren, G. M.;** and **Bouffard, J. A.:** US depiction of partial-thickness tear of the rotator cuff. *Radiology,* 197: 443-446, 1995.
13. **Wiener, S. N.,** and **Seitz, W. H., Jr.:** Sonography of the shoulder in patients with tears of the rotator cuff: accuracy and value for selecting surgical options. *AJR: Am. J. Roentgenol.,* 160: 103-107, 1993.