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SONOGRAPHY AND MAGNETIC RESONANCE IMAGING EQUIVALENT FOR THE ASSESSMENT OF FULL-THICKNESS ROTATOR CUFF TEARS

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Objective. **To investigate the diagnostic value of sonography (SG) and magnetic resonance imaging (MRI) in the assessment of full-thickness rotator cuff tears (RCTs).**

Methods. **Twenty-one consecutive, otherwise healthy patients with noninflammatory unilateral chronic (>3 months) shoulder complaints due to a possible full-thickness RCT were studied (9 women and 12 men, mean ± SD age 56 ± 12). According to standardized procedures, SG was performed by both a radiologist and a rheumatologist, and MRI was evaluated by 2 radiologists. All assessors were blinded to the patient's diagnosis. Within 3 weeks after SG and MRI, arthroscopy was performed. SG, MRI, and arthroscopy results were scored as negative or positive for the presence of a full-thickness RCT. The result of surgical inspection was used as the "gold standard."**

Results. **For full-thickness RCTs, the sensitivity was 0.81 for SG and 0.81 for MRI. The specificity was 0.94 for SG and 0.88 for MRI. The positive predictive value was 0.96 for SG and 0.91 for MRI. The negative predictive value was 0.77 for SG and 0.74 for MRI. Accuracy was 0.86 for SG and 0.83 for MRI.**

Conclusion. **Full-thickness RCTs can be identified accurately by both SG and MRI. Because of its low cost and because it can be performed in the rheumatology unit, SG seems to be a promising diagnostic tool for use by the rheumatologist.**

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Shoulder pathology, such as full-thickness rotator cuff tears (RCTs), is often seen by the rheumatologist, either as a solitary problem or as part of a systemic inflammatory disease. In the first case, mechanical fraying of the rotator cuff is often the main cause of a tear (1). In the latter case, pannus may gradually erode the rotator cuff, causing a tear (2–4). It has been established that tendon degeneration occurs as part of the aging process, and several studies have reported a high incidence of RCTs among the elderly (5–8). Many individuals with a full-thickness RCT are asymptomatic (8,9) or have minimal functional disability (10).

The location of shoulder pain is a poor indicator of its origin (10,11), and the value of clinical assessment of the shoulder is often limited (12). Plain radiography, often used to supplement the clinical examination, is hardly diagnostic for RCTs (13). Traditionally, arthrography (AG) has been used through the years to detect full-thickness RCTs (14,15). Both sonography (SG) (16–20) and magnetic resonance imaging (MRI) (20–22), developed as new imaging techniques in the past 10 years, can be applied to the visualization of shoulder pathology. A recent study (23) has shown that SG and AG are of equal value for the detection of full-thickness RCTs. However, AG is an invasive technique, with up to 50% of patients experiencing more pain 24–48 hours after injection of the contrast material (24). MRI also seems to be a promising technique for shoulder pathology, including RCTs. However, MRI is time-consuming, expensive, and not readily available. On the other hand, due to the specialized expertise required for shoulder SG and the long learning curve, SG might be less available than MRI in some countries.

The results of imaging of the shoulder may have

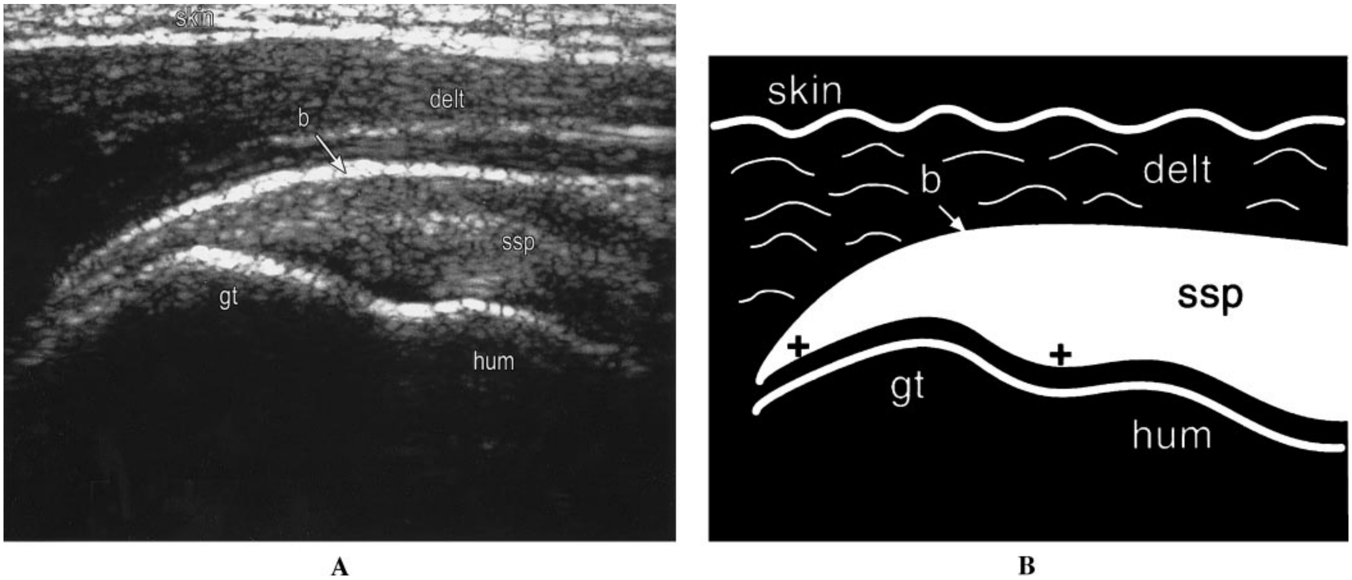

Figure 1. A, Longitudinal sonographic image of a normal rotator cuff. **b** and **arrow** = bursa; **delt** = deltoid muscle; **ssp** = supraspinatus tendon; **gt** = greater tuberosity; **hum** = humerus. **B,** Drawing of the area shown in **A**. The greater tuberosity (**gt**) is found between the + signs.

clinical consequences. Patients with shoulder symptoms from tendinitis and those with partial-thickness tears are advised to continue conservative treatment. If this approach fails to yield improvement within 3–6 months, surgery might be indicated (10,25–27).

Patients with full-thickness RCTs who present with symptoms of impingement but have good shoulder function (compensated by the deltoid muscle) are also advised to continue conservative treatment for 3–6 months. For patients with a full-thickness RCT who have moderate-to-severe weakness and/or loss of active shoulder elevation that is not pain-dependent, surgery is indicated (10). Together with other variables, such as age, occupation, leisure activities, duration of symptoms, and ability of the patient to comply with the postoperative rehabilitation schedule, the finding of a full-thickness RCT may indicate the need for acromioplasty or debridement, with or without cuff repair. Therefore,

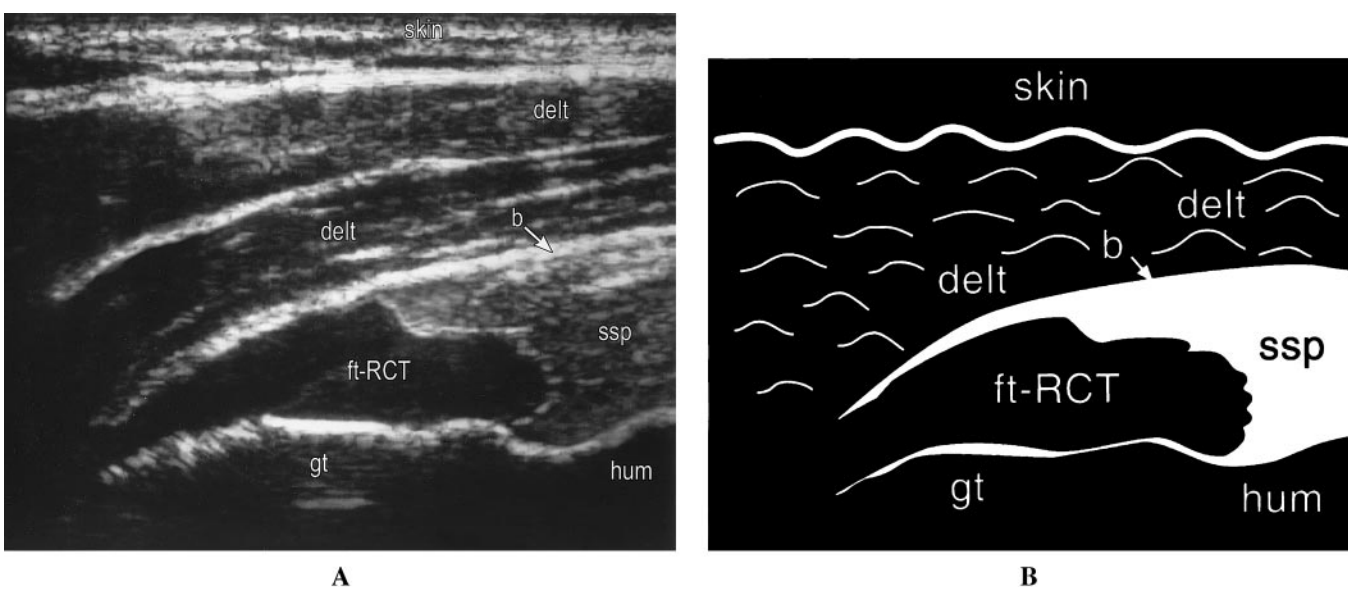

Figure 2. A, Longitudinal sonographic image of a full-thickness rotator cuff tear (**ft-RCT**). **delt** = deltoid muscle; **b** and **arrow** = bursa; **ssp** = supraspinatus tendon; **gt** = greater tuberosity; **hum** = humerus. **B,** Drawing of the area shown in **A.**

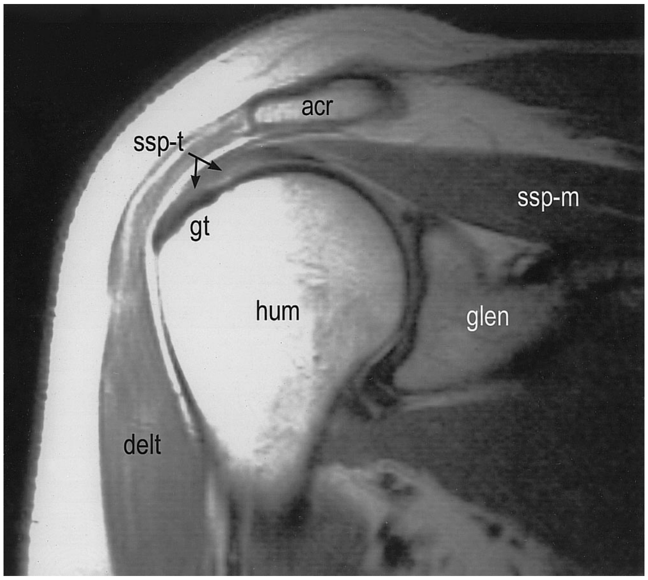

Figure 3. Coronal–oblique proton-density–weighted spin-echo magnetic resonance image (repetition time/echo time 3,000/15 msec) of a normal rotator cuff. **acr** = acromion; **ssp-t** and **arrows** = supraspinatus tendon; **ssp-m** = supraspinatus muscle; **gt** = greater tuberosity; **hum** = humerus; **glen** = glenoid; **delt** = deltoid muscle.

assessment of a full-thickness RCT by means of imaging techniques plays an important role in the choice of therapy.

The purpose of the present study was to evaluate the ability of SG and MRI to detect full-thickness RCTs in patients with a clinically suspected RCT as a solitary, noninflammatory condition.

PATIENTS AND METHODS

Patients. Twenty-one consecutive patients (9 females and 12 males) awaiting surgery because of a clinically suspected RCT were asked to participate in the study. The clinical diagnosis of RCT was established by one of us (WJW), an orthopedic surgeon, based on marked difficulty in initiating abduction of the arm, with weakness and limitation of movement (28,29).

Because pain can cause weakness and thereby mimic an RCT, lidocaine was injected below the acromion (30,31). If after the injection the strength of the rotator cuff was still decreased, this was considered to indicate an RCT (27). Neurologic origins of the weakness were excluded in the study patients.

All patients had unilateral noninflammatory symptoms of the shoulder, with a mean duration of 2.3 years (range 0.3–8 years). The mean age of all patients was 54 years (SD 12). In 4 patients, the shoulder complaints could be attributed to trauma. Informed consent was obtained from all patients.

Sonography. SG was performed twice in the 3 weeks before surgery: once by a radiologist (JR), once by a rheumatologist (WAAS). Both had experience with this technique, and neither was aware of the patient's history or findings of the physical examination. The SG transducers were the 7.5-MHz linear array and the 5.0-MHz curved array (Diasonics, Prisma, Santa Clara, CA). The 7.5-MHz linear array transducer is usually the first choice for shoulder SG. However, in the present study, the 5-MHz curved-array transducer was used for 2 images: the overview of the infraspinatus tendon on longitudinal view of the dorsal aspect of the shoulder and the joint capsule at the humeral head/shaft seen at the axilla. Because of the slightly less superficial structures to be visualized and the anatomical shape of the axilla, the 5-MHz curved-array transducer was used.

SG was performed while the patients were seated, according to the method of van Holsbeeck et al (32). The shoulder was examined in the anterior, lateral, and posterior directions, in both the transverse and the longitudinal planes. For the anterior approach, the patient's upper arm was visualized in internal rotation, which was achieved by placing the patient's hand behind the back. Van Holsbeeck's criteria for full-thickness RCT (32) were used: a discontinuity in the rotator cuff, extending from the bursal to the humeral side of the rotator cuff (Figures 1 and 2).

Magnetic resonance imaging. MRI was performed in the 3 weeks before surgery with a 1.0T system (Impact; Siemens, Erlangen, Germany) with a dedicated shoulder coil as receiver. All patients were placed supine in the magnet. After a T1-weighted (repetition time/echo time 680/15 msec)

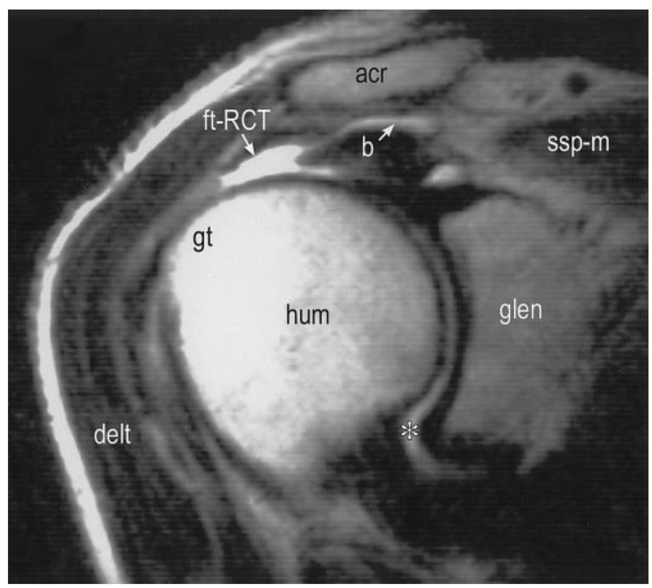

Figure 4. Coronal–oblique T2-weighted spin-echo magnetic resonance image (repetition time/echo time 3,000/105 msec) showing a full-thickness rotator cuff tear (**ft-RCT** and **arrow**). The lesion is identified by fluid that accumulated in the defect of the supraspinatus tendon (**ft-RCT** and **arrow**). Note also fluid in shoulder joint (**white asterisk**) and in the bursa (**b** and **arrow**). **acr** = acromion; **ssp-m** = supraspinatus muscle; **gt** = greater tuberosity; **hum** = humerus; **glen** = glenoid; **delt** = deltoid muscle.

localizing sequence, a standard T2 coronal spin-echo sequence (repetition time/echo time 3.000/15,105 msec) was performed. Oblique coronal images were available for scoring.

The following imaging parameters were used: section thickness 3 mm, with a 1-mm gap, matrix 128 × 256, field of view 8–10 cm, and 1 or 2 excitations. Imaging time ranged from 4 minutes to 8 minutes per sequence, with a total examination time of 45 minutes. A full-thickness RCT was defined as a focal, well-defined area of increased signal intensity on T1-weighted and T2-weighted images that extended through the entire thickness of the tendon (Figures 3 and 4).

The images were evaluated independently by 2 experienced radiologists (PRA and RAM), who were not aware of either the clinical status of the patient or the results of the SG.

Surgical procedure. Surgery was performed by one of us (WJW), an experienced shoulder surgeon. The surgical procedure consisted first of arthroscopic assessment of the rotator cuff by inspection of the glenohumeral joint and the subacromial space. A full-thickness RCT was diagnosed if free communication was found between the bursal and humeral sides of the cuff.

First the arthroscope was introduced in the glenohumeral joint and then into the subacromial space. In the glenohumeral joint, there is a perfect view on the undersurface of the cuff tendons and full-thickness tears can easily be found. For undersurface full-thickness RCTs, glenohumeral arthroscopy is considered to be the diagnostic gold standard. After introducing the scope into the subacromial space, the bursa was removed, especially the bursal floor, to enable a proper examination of the bursal side of the cuff. In the hands of an experienced arthroscopist, arthroscopy of the subacromial space is considered to be the gold standard for detecting full-thickness RCTs as well. In all cases, subacromial decompression was performed, including transection of the coracoacromial ligament. In case of a full-thickness RCT, the cuff was repaired, when possible, through a deltoid-splitting mini-incision.

Statistical analysis. To compare SG and MRI for the assessment of full-thickness RCT, the results were scored as negative when an intact rotator cuff or a partial tear was found and positive when a full-thickness RCT was found. Surgery (the standard against which SG and MRI were evaluated) was scored the same way.

All rotator cuff tendons were evaluated, but only changes in the supraspinatus tendon were analyzed in this study, since RCTs almost always involve the supraspinatus tendon because of the "critical zone" (33). The infraspinatus, teres minor, and subscapularis tendons are usually involved later in the process. However, when trauma is the origin of the shoulder complaint, these tendons can be damaged at the same time as the supraspinatus tendon.

The sensitivity, specificity, and positive and negative predictive values (PPV and NPV) for the detection of full-thickness RCTs were calculated for SG and MRI. Accuracy (percentage of correct results) was also calculated. From the binomial distribution, exact values for 95% confidence intervals (95% CI) were derived. Because of the relatively low number of assessments, the mean values of the 2 MRI and the 2 SG assessments were used after evaluation of the interobserver reliabilities of SG (34) and MRI (35,36) with kappa statistics. To compare the results of full-thickness RCTs demonstrated by SG and surgery versus MRI and surgery, McNemar's tests were applied. Statistical analyses were performed by means of the Number Cruncher Statistical System version 97 (Kaysville, UT).

RESULTS

Of the 21 patients studied, 13 had surgically proven full-thickness RCTs (Table 1). Twelve full-thickness RCTs were assessed correctly by the first SG observer (SG-1) and 9 by the second SG observer (SG-2). The first MRI observer (MRI-1) found 10 full-thickness RCTs, and the other MRI observer (MRI-2) identified 11 full-thickness RCTs on the same MRIs.

These results yielded an average sensitivity of 0.81 for SG (95% CI 0.51–0.95) (Table 2) and 0.81 for MRI (95% CI 0.50–0.97) (Table 3), an average specificity of 0.94 for SG (95% CI 0.55–1.0) and 0.88 for MRI (95% CI 0.47–1.0). For a full-thickness RCT, the average PPV was 0.96 for SG (95% CI 0.65–1.0) and 0.91 for MRI (95% CI 0.60–1.0), and the average NPV was 0.77 for SG (95% CI 0.41–0.95) and 0.74 for MRI (95% CI 0.37–0.95). The mean accuracy was 0.86 for SG (95% CI 0.64–0.97) and 0.83 for MRI (95% CI 0.61–0.96). Interobserver reliability test results were 0.63 for SG and 0.52 for MRI. The number of false results of MRI was not statistically significantly different from the number of false results of SG.

Among the 21 patients, 4 had a serious trauma as the origin of their shoulder complaints. Only 2 patients had a full-thickness RCT of the infraspinatus tendon. No full-thickness RCT of the subscapularis or teres minor tendons were found.

DISCUSSION

For the evaluation of patients with acute and longstanding shoulder pain attributable to rotator cuff pathology, imaging techniques are indispensable. For the imaging of soft tissues around the shoulder, AG, SG, and MRI are available. AG is accepted as the gold standard for the detection of full-thickness RCTs. Newer imaging techniques, such as SG and MRI, have been compared with AG over the last 15 years. The advantages and disadvantages of one imaging technique compared with the other demonstrate that these 3 techniques can be considered supplementary. Double-contrast shoulder AG studies have reported sensitivities and specificities ranging from 0.71 to 1.0 (14,15, 23,37,38). Because of a recent comparative study (23) that showed that AG and SG were equivalent in detect-

Table 1. Results of imaging and surgery*

	Patient number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Surgery	–	–	–	+	+	+	+	–	+	+	+	+	–	–	–	+	+	–	+	+	+
SG-1	–	–	–	+	+	+	+	–	+	+	+	+	–	+	–	+	–	–	+	+	+
SG-2	–	–	–	+	+	+	+	–	+	–	+	+	–	–	–	–	–	–	–	+	+
MRI-1	–	–	–	+	+	+	+	–	+	–	+	–	–	+	–	+	+	–	–	+	+
MRI-2	–	–	+	+	+	+	+	–	+	–	+	+	–	–	–	+	+	–	+	+	–

* + = presence and – = absence of a full-thickness rotator cuff tendon tear. SG = sonography; MRI = magnetic resonance imaging; 1 = observer 1; 2 = observer 2.

ing full-thickness RCTs and because of the noninvasive nature of SG and MRI as imaging techniques, AG was not included in the present study. Partial tears cannot be visualized reliably by SG (39) and MRI (13). Furthermore, the clinical relevance of partial tears is unclear. For these reasons, we did not include partial tears in our analyses.

In the present study, acromioplasty was performed in all patients. In general, however, there is no need to perform acromioplasty in all cases of a full-thickness RCT. For a full-thickness RCT that can be repaired, one should consider acromioplasty only when a biomechanical cause of the tear is assumed, e.g., a hooked acromion (type 3 according to Bigliani) or an osteophyte. When an "intrinsic" cause of tearing of the cuff is presumed, or when the cuff is not repairable, debridement of the cuff edges is performed, but acromioplasty generally is not indicated.

Sonography. The mean sensitivity (0.81), specificity (0.94), PPV (0.96), NPV (0.77), and accuracy (0.86) of SG as found in the present study are consistent with data reported in the literature (Table 2).

Alasaarela et al (40) made an interesting observation in their study of 19 inpatients with chronic arthritis. They demonstrated a lower value for SG for the assessment of full-thickness RCTs. However, their study included patients with partial tears. Three patients with an advanced stage of rheumatoid arthritis (RA) were included. In all 3 cases, SG detected a full-thickness RCT while surgery showed an intact, but membranous, thin rotator cuff. This suggests that in advanced stages of RA, SG assessment of the rotator cuff may become more difficult. Results of surgery in 1 of their patients were not applicable.

Sonnabend et al (41) showed that SG is reliable for the detection of full-thickness RCTs, with a PPV of 0.88 and surgery being the gold standard. However, the study inclusion criteria were not described. Those authors started the study with 117 patients, but on review of the published data, we only found 110 patients.

In our recent study of 48 patients with unilateral chronic shoulder complaints without an underlying inflammatory rheumatic disease (23), high values were found for SG imaging of full-thickness RCTs, with surgery being the gold standard.

In their study of 200 patients with signs and symptoms suggesting a tear of the rotator cuff, Takagishi et al (19) found a sensitivity of 0.76 for the detection of full-thickness RCTs proven by surgery in 122 of their patients. In the other 78 cases, however, SG was not followed by surgery; the authors did not explain why.

The largest study of patients with signs and

Table 2. Statistical results of assessment of full-thickness rotator cuff tears by sonography*

Author, year (ref.)	No. of patients	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
Present study	21	81	94	96	77	86
Alasaarela et al, 1998 (40)	19	82	63	75	71	74
Swen et al, 1998 (23)	48	86	88	86	88	88
Sonnabend et al, 1997 (41)	110	84	92	88	90	89
Takagishi et al, 1996 (19)	122	76	10	10	90	93
Wiener et al, 1993 (17)†	225	93	99	99	96	97

* For all studies, comparisons were of full-thickness rotator cuff tears versus no or partial tears by sonography (surgical inspection being the gold standard). Data were recalculated, when necessary, from the original article.
† These data are not fully reliable, because only 225 of 800 patients underwent both sonography and surgery; the remaining 575 patients had normal findings on sonograms and no surgical followup.

Table 3. Statistical results of assessment of full-thickness rotator cuff tears by magnetic resonance imaging*

Author, year (ref.)	No. of patients	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
Present study	21	81	88	91	74	83
Balich et al, 1997 (36)	222	90	95	84	98	94
Wnorowski et al, 1997 (48)†	38	56	73	38	85	69
Quinn et al, 1995 (49)	100	85	99	94	96	96
Farley et al, 1992 (47)‡	112	70	96	86	89	89
Iannotti et al, 1991 (46)§	88	10	95	92	10	97

* For all studies, comparisons were of full-thickness rotator cuff tears (RCTs) versus no or partial tears by magnetic resonance imaging (surgical inspection being the gold standard). Data were recalculated from the original article.
† Results from community hospital radiologists were used for calculations.
‡ Results as presented by the authors do not clarify whether full-thickness RCTs were compared with no or partial tears.
§ Ninety-one patients are mentioned, but data from only 88 patients were used for the calculations.

symptoms of a rotator cuff tear (n = 800) that we found in the literature was performed by Wiener, a radiologist, and colleagues (17). Those investigators found high values for SG imaging of full-thickness RCTs, with surgery as the gold standard (n = 225). A potential limitation of that study was the lack of analysis of the other 575 patients with normal findings on sonograms and no surgical followup. Exclusion of these patients made it impossible to determine the true-negative and false-negative rates. Therefore, the sensitivity, specificity, and NPV cannot be calculated reliably (39).

The results of earlier studies on shoulder SG and RCTs exhibit the same range of outcomes. Mack et al (42) and Middleton et al (43) obtained sensitivities of >0.90, while Brandt et al (44) and Miller et al (45) reported sensitivities of <0.80.

The differences in results may be due to differences in the selection of patients, SG techniques, and/or level of experience of the investigators (39). The SG studies were performed by different medical specialists (radiologist, orthopedic surgeon, rheumatologist), and the results were comparable to the present study, in which SG was performed twice, once by a rheumatologist and once by a radiologist. This illustrates that SG results are dependent mainly on the experience of the examiner, rather than his or her specialty. The above-mentioned SG studies, which differed with regard to the origin of the full-thickness RCTs, ranging from mechanical trauma to inflammation, confirm the consistency of the results, regardless of the origin of the full-thickness RCTs.

Our experimental study was performed in a blinded manner (neither the radiologist nor the rheumatologist had any knowledge of the patient's history and physical examination findings) to enable a fair comparison between the 2 techniques. We believe, however, that in daily clinical practice, it would be very useful for the sonographer to be informed about both the patient's history and physical findings.

SG has been accepted as a screening tool and even as a final diagnostic method by many investigators. However, there seems to be a high interobserver variation in the demonstration of full-thickness RCTs with SG (34). In the literature, we found no data on this interobserver variation. In the present study, SG yielded a reliability of 0.63, indicating fair reliability.

In the Netherlands, shoulder SG costs \$52; MRI costs almost \$208. In the United States, shoulder SG costs \$183, while MRI costs \$1,238 (13).

Magnetic resonance imaging. In the present study, the mean sensitivity (0.81), specificity (0.88), PPV (0.91), NPV (0.74), and accuracy (0.83) of MRI for full-thickness RCTs did not differ very much from values reported in the literature (Table 3).

In a study of inpatients with chronic arthritis, Alasaarela et al (20) concluded that MRI is a better tool than SG for the assessment of full-thickness RCTs. They did not, however, use surgery as the gold standard.

Iannotti et al (46) found high values in their study of MRI for full-thickness RCTs in 88 patients. The inclusion criteria for that study were not described, however.

Farley et al (47) obtained lower values for MRI of full-thickness RCTs compared with surgery in their study of 112 patients. Unfortunately, the inclusion criteria for that population were also not stated.

Wnorowski et al (48) compared the accuracy of MRI interpretation of rotator cuff integrity by a group of community hospital radiologists with that of a group of musculoskeletal radiologists, relative to arthroscopy. The community hospital radiologists scored far lower than the musculoskeletal radiologists. That retrospective study consisted of 38 patients who visited the outpatient department of orthopedic surgery for a solitary shoulder complaint.

In a study of MRI/arthroscopy of 100 patients with a full-thickness RCT, Quinn et al (49) found a sensitivity and specificity of 0.85 and 0.99, respectively. All patients had clinically suspected subacromial impingement.

Considering all these findings, therefore, MRI, like SG, seems to be dependent on various factors, including the experience of the radiologist and the difficulty in distinguishing a partial from a full-thickness RCT by means of MRI (13,21,48–50). Furthermore, there are no uniformly accepted MRI criteria for the diagnosis of RCTs (47).

Interobserver agreement for MRI of the rotator cuff tendon was investigated by Balich et al (36). Five radiologists with various levels of experience twice interpreted independently the MRIs of 222 symptomatic patients who underwent both MRI and shoulder arthroscopy. The first interpretation was a blinded assessment; the second was with knowledge of the arthroscopic findings. For full-thickness RCTs, the ranges of sensitivity, specificity, and accuracy were 0.84–0.96, 0.94–0.98, and 0.92–0.97, respectively. The mean of 5 readers was used in Table 3. The interobserver agreement (kappa values) varied from 0.73 to 0.88.

Robertson et al (35) retrospectively reviewed the interobserver variation in the diagnosis of full-thickness RCT by means of MRI among 74 patients who underwent surgery. Kappa values for reliability were calculated. All 4 observers were highly accurate in the diagnosis of a full-thickness RCT (0.89–0.98), with good interobserver agreement (κ = 0.74–0.92).

In our study, the kappa value for reliability was 0.52 for MRI, indicating a fair result. Interobserver variation in MRI, in general, may be considerable, as has been demonstrated for evaluation of the knee (51) as well as for many other areas (52). In general, full-thickness RCTs, however, can be identified accurately by MRI (46).

In conclusion, SG is as reliable as MRI for visualizing a full-thickness RCT. Detection of a full-thickness RCT in a patient with therapy-resistant shoulder pain plays a major role in the choice between conservative treatment and surgery. Depending on the experience of the examiner, SG might be the imaging technique of choice for detecting full-thickness RCTs. SG is less expensive, less time-consuming, more dynamic, and less demanding for the patient compared with MRI.

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Erratum

In the first sentence of the letter to the editor by Bresnihan et al published in the August 1999 issue of *Arthritis & Rheumatism* (p 1782), the dosage of human interleukin-1 receptor antagonist was incorrectly stated. The dosage should have been 150 mg/day. We regret the error.