Systematic Review

Does the Literature Confirm Superior Clinical Results in Radiographically Healed Rotator Cuffs After Rotator Cuff Repair?

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Purpose: Because recurrent or persistent defects in the rotator cuff after repair are common, we sought to clarify the correlation between structural integrity of the rotator cuff and clinical outcomes through a systematic review of relevant studies. **Methods:** Medline, CINAHL (Cumulative Index to Nursing and Allied Health Literature), and the Cochrane Central Register of Controlled Trials were searched for all literature published from January 1966 to December 2008 that used the key words shoulder, rotator cuff, rotator cuff tear, rotator cuff repair, arthroscopic, integrity, healed, magnetic resonance imaging (MRI), computed tomography arthrography (CTA), and ultrasound. The inclusion criteria were studies (Levels I to IV) that reported outcomes after arthroscopic rotator cuff repair in healed and nonhealed repairs based on ultrasound, CTA, and/or MRI. Exclusionary criteria were studies that included open repair or subscapularis repair and studies that did not define outcomes based on healed versus nonhealed but rather used another variable (i.e., repair technique). Data were abstracted from the studies including patient demographics, tear characteristics, surgical procedure, rehabilitation, strength, range of motion, clinical scoring systems, and imaging studies. **Results:** Thirteen studies were included in the final analysis: 5 used ultrasound, 4 used MRI, 2 used CTA, and 2 used combined CTA/MRI for diagnosis of a recurrent tear. Statistical improvement in patients who had an intact cuff at follow-up was seen in Constant scores in 6 of 9 studies; in University of California, Los Angeles scores in 1 of 2 studies; in American Shoulder and Elbow Surgeons scores in 0 of 3 studies; and in Simple Shoulder Test scores in 0 of 2 studies. Increased range of motion in forward elevation was seen in 2 of 5 studies and increased strength in forward elevation in 5 of 8 studies. **Conclusions:** The results suggest that some important differences in clinical outcomes likely exist between patients with healed and nonhealed rotator cuff repairs. Further study is needed to conclusively define this difference and identify other important prognostic factors related to clinical outcomes. **Level of Evidence:** Level IV, systematic review.

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The surgical treatment of rotator cuff tears has evolved from open repair with transosseous sutures to, more recently, all-arthroscopic techniques with single-row, double-row, or transosseous-equivalent suture anchor configurations. With each improvement, the question remains whether these implemented advances translate into better clinical and functional results. Several studies have shown that there are no clinical differences between patients treated with an open or arthroscopic rotator cuff repair.[1,2] Furthermore, significant differences in clinical outcome between single- and double-row or transosseous-equivalent techniques have yet to be shown clinically.[3,4]

Over the past several years, there has been enormous interest in finding a clinical result that would correlate with improved patient outcomes, satisfaction, and function. Conventional thinking led investigators to hypothesize that rotator cuff repairs that healed would naturally be less symptomatic and more functional than those that did not fully heal.[5] Initial studies in an open repair setting had conflicting results, with radiographic failure in 33% to 85%.[6,7] Harryman et al.,[5] in a landmark article, showed increased function and range of motion in patients who had an intact rotator cuff repair after open repair. Since that publication, multiple authors have shown superior tendon healing with a variety of surgical techniques, although differences in clinical and functional results between patients with intact cuffs and those with recurrent defects have not been significant. Although there are apparent differences in some of the clinical findings, it is difficult to compare results across several case series with wide variations in patient demographics, rotator cuff tear characteristics and associated pathology, surgical technique, clinical outcomes, and imaging studies.

We designed a qualitative systematic review of the published literature to compare the clinical outcomes of healed versus nonhealed rotator cuff repairs after arthroscopic rotator cuff repair. Our hypothesis was that clinical studies comparing arthroscopic healed versus nonhealed rotator cuff repairs do not show a significant difference between subjective and objective outcome measures for patients with intact rotator cuffs versus those with recurrent defects.

METHODS

Literature Search

We searched Medline, CINAHL (Cumulative Index to Nursing and Allied Health Literature), and the Cochrane Central Register of Controlled Trials for all literature published from January 1966 to December 2008 using the following key words: shoulder, rotator cuff, rotator cuff tear, rotator cuff repair, arthroscopic, integrity, healed, magnetic resonance imaging (MRI), computed tomography arthrography (CTA), and ultrasound. General search terms were chosen to prevent the possibility of missing potential studies. Studies that were only presented as abstracts were not included in the final analysis. To ensure that all possible articles were considered, the references of all relevant articles and review articles were manually cross-referenced. Inclusion criteria were all studies that compared the results between healed and nonhealed rotator cuff repairs performed arthroscopically, including all sizes of tears. Exclusion criteria were studies that included open repairs or subscapularis repairs and studies that did not define outcomes based on healed versus nonhealed but rather used another variable (i.e., double row *v* single row). Patient demographic information, rotator cuff tear characteristics, operative technical details, objective and subjective outcome measurements, and complications were abstracted from the studies.

Data Abstraction

The data from all of the studies that met the inclusion criteria were abstracted by 2 independent reviewers. Demographic data collected included the type of study, Level of Evidence, number of patients enrolled, number of patients in final follow-up, age, gender, dominant extremity, follow-up, and duration of symptoms. The classification of rotator cuff tear size of DeOrio and Cofield[8] was used to categorize the treatment groups in terms of percent of patients with small (<1 cm), medium (1 to 3 cm), large (3 to 5 cm), and massive (>5 cm) rotator cuff tears. Rotator cuff tear patterns were also classified as crescent, L shaped, reverse L shaped, V shaped, and U shaped.[9] Concomitant procedures performed were also recorded. The percentage of satisfied or very satisfied patients for each group was obtained if noted in the study. Preoperative and postoperative data including range of motion, strength, and clinical and subjective outcome scales (Constant-Murley[10]; University of California, Los Angeles [UCLA][11]; American Shoulder and Elbow Surgeons [ASES][12]; Short Form 36 [SF-36][13]; Pennsylvania Shoulder Score[14]; L'Insalata[15]; and visual analog pain scale) were extracted. In addition, complications were noted and categorized into major or minor and medical related or orthopaedic related.

The method of postoperative imaging modality was also recorded in addition to how long after surgery the imaging was performed. The data were collected in table format by use of Excel (Microsoft, Redmond, WA), and no statistical comparisons were performed as part of the systematic review.

RESULTS

Literature Search

There were 640,597 articles found with all of the general search terms; these were limited to the English language and human subjects, leaving 441,432 articles. Each of the search terms was then combined with one other term by use of PubMed advanced search to locate those pertinent to the study. The abstracts of each of the combined searches were then reviewed to determine appropriateness for inclusion in the study. There were 35 articles that were deemed appropriate for the analysis. Of the 35 articles, 21 were excluded after a full-text review. Nine studies were excluded because they compared healing rates and outcomes after open repair.[5,16-23] Three articles that compared open and arthroscopic repairs were excluded.[2,24,25] Articles that examined repair integrity after subscapularis repair only (2 studies) were also excluded.[26,27] Three studies were excluded because they examined healing rates only after arthroscopic rotator cuff repair, and no outcomes or results based on integrity were given.[28-30] One study, by Sugaya et al.,[31] was excluded because it reported outcomes based on the structural thickness of the repair. Outcomes for this study were not able to be classified based on intact or nonintact cuff after arthroscopic rotator cuff repair. Another study, by Lichtenberg et al.,[32] was excluded after full-text review showed that the patient cohort was the same cohort used in another published article by Liem et al.[24] (included in the analysis). An additional 3 studies were excluded because they compared integrity of rotator cuff repair with other variables such as double- versus single-row repair and not with clinical outcomes.[33-35] There were 13 studies that met the final criteria that compared rotator cuff integrity after arthroscopic repair with clinical outcomes and were included in the final data analysis.[36-48]

Patient Demographics

The study design, Level of Evidence, total number of patients, number of shoulders evaluated, number of patients in each group (intact *v* return), and percent of effective follow-up were included in our analysis (Table 1). All studies that were included in this systematic review were Level IV studies composed of case series. The studies included had an effective follow-up rate between 53% and 100%. The percentage of healed rotator cuff repairs averaged between 58.5% and 88.6% in the studies included. There were a total of 1,472 patients included in all the studies, of whom 1,171 had intact rotator cuff repairs at the time they were evaluated for a combined healing rate of 79.6% after arthroscopic rotator cuff repair. Many of the studies compared demographics between healed and nonhealed groups to determine whether there was any correlation with healing. Seven of the studies exam-

TABLE 1. *Patient and Study Demographics for Studies Comparing Healed Versus Nonhealed Groups in Patients Undergoing Arthroscopic Rotator Cuff Repair*

Source	Study	Level of Evidence	Total No. of Shoulders	No. of Shoulders Evaluated	No. of Shoulders in Healed Group	% Healed	Effective Follow-up	Dominant	Mean Follow-up (mo)	Percentage of Male Patients	Percentage of Workers' Compensation Cases
Anderson et al.[36]	Case series	IV	52	52	43	82.7	100%	NR	30	63%	NR
Boileau et al.[37]	Case series	IV	85	65	46	70.8	76%	77%	29	49%	NR
Charousset et al.[39]	Case series	IV	114	102	66	64.7	89%	84%	31	46%	NR
Lafosse et al.[44]	Case series	IV	197	105	93	88.6	53%	80%	36	49%	NR
Cole et al.[40]	Case series	IV	55	49	38	77.6	89%	71%	32	NR	47%
Castagna et al.[38]	Case series	IV	29	29	18	62.1	100%	70%	30	72%	NR
DeFranco et al.[41]	Case series	IV	30	30	18	60.0	100%	NR	22	60%	NR
Frank et al.[42]	Case series	IV	25	25	22	88.0	100%	NR	NR	55%	NR
Liem et al.[45]	Case series	IV	53	53	40	75.5	100%	NR	26	NR	NR
Oh et al.[47]	Case series	IV	78	53	31	58.5	67%	77%	20	55%	NR
Nho et al.[46]	Case series	IV	193	127	96	75.6	66%	NR	28	NR	NR
Huijsmans et al.[43]	Case series	IV	264	206	174	84.5	78%	62%	22	NR	NR
Flurin et al.[48]	Case series	IV	756	576	486	84.4	80%	80%	19	52%	17%

NOTE. Rates of rotator cuff healing from 60% to 89% can be expected after rotator cuff repair.
Abbreviation: NR, not reported.

ined found a significant difference in the age of the patients, with younger patients being more likely to have a healed rotator cuff after arthroscopic repair.[37,38,40,41,45-47] Several of the studies looked at the effect of rotator cuff tear size to determine whether initial tear size could affect the likelihood of having a healed tendon at follow-up. Four of the studies found that initial tear size did affect the tendon healing, with larger tears being more likely to not heal after repair.[36,40,43,46] Four studies found no correlation between tear size and the likelihood of anatomic healing.[42,44,45,47] The study by Boileau et al.[37] did note that delamination of the cuff at arthroscopy was noted to affect the healing rate postoperatively. The other 4 studies made no mention of whether tear size affected the chance of having a radiographically healed rotator cuff repair. Other patient demographics such as arm dominance, gender, or Workers' Compensation were not found to be significant in any of the studies that looked at these variables in comparison to cuff integrity.

Surgical Technique

Because of the inclusionary criteria for this systematic review, all studies used arthroscopic rotator cuff repair with suture anchor fixation. Three of the studies used a double-row technique that incorporated a medial and lateral row of suture anchors to repair the rotator cuff.[36,43,44] Five of the studies used single-row suture anchor fixation to accomplish the rotator cuff repair.[38-41,45] There was variability between the studies as to whether this single row was placed medially or laterally. Transosseous-equivalent all-arthroscopic repair was performed in 2 of the studies, where sutures are brought over the lateral tendon to re-create the rotator cuff footprint.[37,42] Very few of the studies indicated how many anchors were used, and the number mostly depended on the size and tear configuration. If mention of the type of anchor used was made, the same type of anchor was used in both patients who had an intact rotator cuff and those with a torn rotator cuff at follow-up, maintaining consistency. However, in those studies in which several surgeons were involved, there was variability in the type of anchor used.[48]

Subacromial decompression was performed in all patients in 5 of the studies and in the majority of patients in another 3 studies. Other studies either mentioned the criteria for their decision to perform subacromial decompression or did not mention whether subacromial decompression was performed. In the studies in which concomitant pathology was mentioned, acromioclavicular and biceps pathology was the most prevalent. Distal clavicle resection or acromioclavicular joint coplaning was performed for acromioclavicular pathology in 6% to 24% of the cases in which statistics were given.[37,42,46] Biceps pathology was treated differently in most studies, with biceps tenodesis being performed in 2%[33] to 82%[37] of cases and tenotomy being performed in 3%[41] to 57%.[33] There was only 1 study that did not give percentages of concomitant procedures performed.[43] Capsulotomy was performed in 15% of the cases in the study by Flurin et al.[48] to mobilize the rotator cuff to facilitate repair.

Rehabilitation Protocol

The postoperative rehabilitation was only mentioned briefly in each study. However, the rehabilitation was the same for each group, and thus it was believed that the rehabilitation protocols should not bias outcomes based on integrity after arthroscopic rotator cuff repair.

Range of Motion

There were 5 studies that reported range of motion as an outcome variable related to anatomic rotator cuff healing.[36,40,43,44,46] Three of the studies found no statistical significance with regard to range of motion with both healed and radiographically nonintact repairs having comparable range of motion (forward elevation) at final follow-up.[36,44,46] Two of the studies did show statistically significantly improved forward elevation in those patients who had an intact rotator cuff repair.[40,43] Both studies showed a 10° increase in forward elevation in patients with an intact rotator cuff. External rotation was mentioned in only 3 studies, with only the study by Cole et al.[40] showing a statistical difference in patients with an intact cuff. The study by Anderson et al.[36] was the only study to look at internal rotation, and it found no difference between intact and nonintact repairs.

Strength

Eight studies provided strength measurements as an outcome, four of which presented their data as the strength component of the Constant score (Table 2).[37,43,45,48] Two of the studies measured strength in forward elevation in kilograms using an instrumented device.[40,44] Anderson et al.[36] devised the shoulder strength index, which is the muscular strength of the affected shoulder divided by the strength of the con-

TABLE 2. *Strength of Healed Versus Nonhealed Rotator Cuff Repairs in Forward Elevation After Arthroscopic Repair*

Source	Strength		*P* Value
	Healed	Nonhealed	
Anderson et al.[36]	SSI, 1.05	SSI, 0.62	.06
Boileau et al.[37]	14.6*	9.4*	.001
Charousset et al.[39]	NR	NR	NR
Lafosse et al.[44]	12.9†	11.4†	.32
Cole et al.[40]	5.8†	3.9†	.05
Castagna et al.[38]	NR	NR	NR
DeFranco et al.[41]	NR	NR	NR
Frank et al.[42]	NR	NR	NR
Liem et al.[45]	13.9*	8.4*	.043
Oh et al.[47]	NR	NR	NR
Nho et al.[46]	4.9‡	4.5‡	.086
Huijsmans et al.[43]	4.2*	2.4*	.001
Flurin et al.[48]	14.5*	10.7*	<.001

NOTE. Five of the eight studies that reported strength found a statistically significant difference.

Abbreviations: SSI, shoulder strength index of affected/contralateral shoulder in forward elevation; NR, not reported.

*Constant score (strength in forward elevation).

†Kilograms of strength in forward elevation.

‡Degrees of strength in forward elevation (out of 5).

tralateral shoulder. Nho et al.[46] measured strength in forward elevation using 5° strength measurements. All of the studies except those of Anderson et al., Lafosse et al.,[44] and Nho et al. found a significant difference in strength in forward elevation between those patients who had a healed rotator cuff repair and those who did not. Only Anderson et al. and Nho et al. reported on external rotation strength, and both studies found a significant difference between healed and nonhealed rotator cuff repairs. Of note, Charousset et al.[33] reported in their study that tendon healing was predictive of strength recovery; however, no numbers were given, and therefore this article was not included with the previously mentioned articles as specifically addressing strength.

Postoperative Shoulder Scores (Constant, UCLA, ASES, Simple Shoulder Test, and so on)

In terms of shoulder functional outcome scores, 9 studies used the Constant score, 2 used the UCLA score, 3 used the ASES score, 3 used the Simple Shoulder Test (SST) (1 did not comment on significance), 1 used the SF-36, 1 used the Pennsylvania Shoulder Score, and 1 used the L'Insalata score (Table 3). Each of the studies found significant differences when comparing preoperative and postoperative scores.

TABLE 3. *Functional Outcome Scores of Healed Versus Nonhealed Rotator Cuff Repairs After Arthroscopic Repair*

Source	Constant Score			ASES Score			L'Insalata Score			Pennsylvania Shoulder Score			Visual Analog Pain Scale		
	Healed	Nonhealed	*P* Value	Healed	Nonhealed	*P* Value	Healed	Nonhealed	*P* Value	Healed	Nonhealed	*P* Value	Healed	Nonhealed	*P* Value
Anderson et al.[36]	NR	NR	NR	NR	NR	NR	91.60	94.3	.82	NR	NR	NR	NR	NR	NR
Boileau et al.[37]	85.7	78.9	.02	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Charousset et al.[39]	83	73.6	.002	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Lafosse et al.[44]	80.8	76.4	.17	NR	NR	NR	NR	NR	NR	NR	NR	NR	13.3	11.2	.02
Cole et al.[40]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.4	1.5	NS
Castagna et al.[38]	72.78	55.27	<.001	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
DeFranco et al.[41]	NR	NR	NR	NR	NR	NR	NR	NR	NR	95.5	83.2	<.01	NR	NR	NR
Frank et al.[42]	89.92	88	NS	92.14	97.22	NS	NR	NR	NR	NR	NR	NR	NR	NR	NR
Liem et al.[45]	86.1	78.9	<.0001	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Oh et al.[47]	68.9	69.7	NS	85.9	92.4	NS	NR	NR	NR	NR	NR	NR	2.0	1.0	NS
Nho et al.[46]	NR	NR	NR	93.9	88	NS	NR	NR	NR	NR	NR	NR	NR	NR	NR
Huijsmans et al.[43]	81.2	76	.002	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Flurin et al.[48]	84.09	78.36	<.001	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

NOTE. Significant improvement was shown in Constant scores in 6 of 9 studies, UCLA scores in 1 of 2 studies, ASES scores in 0 of 3 studies, and SST scores in 0 of 2 studies.

Abbreviations: NS, nonsignificant; NR, not reported.

Of the 9 studies that examined Constant scores, 6 found a significant difference in outcome between healed and nonhealed rotator cuff repairs.[37-39,43,45,48] The 3 studies that found no significance in overall Constant scores were performed by Oh et al.,[47] Frank et al.,[42] and Lafosse et al.[44] However, Lafosse et al. did stratify Constant scores according to the different categories, and they did find a difference in the pain component of the Constant score. Flurin et al.[48] performed the only other study that stratified Constant scores, and they found that all components (activity, mobility, and strength) were statistically significant ($P < .001$); however, the pain component was not.

UCLA scores were reported in 2 studies, 1 of which reported no statistical difference between patients with healed rotator cuff repairs and those with nonintact repairs.[38] The study by Frank et al.[42] did find a statistically higher score in patients with healed rotator cuff repairs. All 3 of the studies that reported ASES scores found no statistically significant difference between healed and nonhealed rotator cuff repairs.[42,46,47] The differences in SST were also found not to be statistically significant between the 2 groups in the studies by Frank et al. and Oh et al.[47] L'Insalata scores were reported in the study by Anderson et al.[36]; no difference in the outcome scores was found between retears and healed rotator cuffs ($P = .82$).

The study by DeFranco et al.[41] was the only one to report outcomes based on the SF-36 and Pennsylvania Shoulder Score. In their study, with regard to the Pennsylvania Shoulder Score, they found statistically significantly lower scores in patients with nonintact repairs for pain and function, as well as overall, but not for satisfaction. SF-36 outcomes showed statistically higher scores in patients with intact cuffs in the overall mental component score but not in the overall physical component score. Three studies reported on visual analog pain scale findings: one found a statistically lower pain score in patients with an intact rotator cuff repair,[44] and the other two found no difference.[40,47]

Satisfaction levels were reported in 3 studies, with 2 of the studies finding no statistical difference in satisfaction between healed and nonhealed repairs[37,47] and 1 making no comment on statistical difference.[38]

To ascertain whether each of the studies that met the criteria for inclusion in our systematic review were properly powered, a post hoc power analysis was performed for each study. Several assumptions were made to determine the power of each study. For each study, we analyzed the outcome scale that the primary author used (Constant, ASES, and so on). A 10-point difference was used as a clinically significant difference between healed and nonhealed rotator cuffs for each of the outcome scales. With these assumptions, 7 of the 13 studies included in this systematic review had enough power to answer the question that they attempted to answer.[37,39,43,44,46-48] Of the studies powered appropriately, 4 showed a significant clinical difference between healed and nonhealed repairs whereas 3 did not.

Imaging Studies

There was a large variability in the radiographic modalities used to determine the presence of a retear after rotator cuff repair (Table 4). Of the 13 studies included, 5 used ultrasound to determine whether a retear was present.[36,38,41,43,46] Three of the groups of investigators used MRI to determine the intactness of their repairs.[40,42,45] CTA was used exclusively in 2 studies,[39,47] whereas both CTA and MRI were used in another 3 studies.[37,44,48] The time frame for obtaining the radiographic studies after surgery also was quite variable. All studies that mentioned when the radiographic studies were performed waited a minimum of 6 months to image their patients. Three studies had a minimum time of 6 months after surgery to reimage their patients,[37,39,44] and three waited until after 12 months.[42,45,47] Another 4 studies waited until 24 months after surgery to reimage their patients.[38,40,43,46]

TABLE 4. *Radiographic Modalities Used for Determining Presence of Healed or Nonhealed Rotator Cuff After Arthroscopic Repair*

Source	Radiographic Study	Minimum Time From Surgery	Mean Time From Surgery
Anderson et al.[36]	US	NR	NR
Boileau et al.[37]	CTA, MRI	6 mo	NR
Charousset et al.[39]	CTA	6 mo	NR
Lafosse et al.[44]	CTA, MRI	6 mo	23 mo
Cole et al.[40]	MRI	24 mo	NR
Castagna et al.[38]	US	24 mo	30 mo
DeFranco et al.[41]	US	NR	NR
Frank et al.[42]	MRI	NR	15 mo
Liem et al.[45]	MRI	NR	14 mo
Oh et al.[47]	CTA	12 mo	NR
Nho et al.[46]	US	24 mo	NR
Huijsmans et al.[43]	US	22 mo	NR
Flurin et al.[48]	MRI, CTA	NR	NR

NOTE. There was no consistency in radiographic study used or how long after surgery this study was used to determine whether a rotator cuff tear was healed after arthroscopic repair.

Abbreviations: US, ultrasound; NR, not reported.

Three of the studies did not mention when the radiographic modalities were used after surgery.[36,41,48]

Huijsmans et al.[43] imaged patients with ultrasound both at 3 weeks and then at a mean of 22 months after surgery to determine whether there was a difference in the retear rate as time progresses between the early postoperative period and final follow-up (mean, 22 months). Interestingly, they found that 16 of 206 patients (7.8%) retore their rotator cuff within the first 3 weeks, and the same number had torn their rotator cuff between 3 weeks and 22 months. The majority of these retears (>50%) occurred in patients with massive rotator cuff repairs, with 34% of patients tearing their rotator cuff within the first 3 weeks.

Complications

There were no unusual complications reported in any of the studies; however, 7 of the studies did not specifically state which complications occurred.[36,41,42,45-48] There were a total of 33 complications in the studies that reported them. In all of the studies there were no deep infections but there were 5 superficial infections. Only 6 patients had to undergo reoperation for either anchor pullout or bursectomy/suture removal. There were 9 cases of arthrofibrosis.

Overall Retear Rate

Included in the 13 studies in this systematic review were a total of 1,931 shoulders that had an arthroscopic rotator cuff repair. Of the patients, 1,472 were evaluated postoperatively for the presence of a persistent defect with either ultrasound, MRI, or CTA (effective follow-up rate, 76%). Of the 1,472 patients evaluated with a radiographic study, 1,171 had an intact cuff, for a 79.6% rate of healing after arthroscopic rotator cuff repair.

DISCUSSION

As surgical techniques for arthroscopic rotator cuff repair become more advanced and less invasive, hopefully, patient satisfaction after surgery will continue to improve. Of concern is that despite high patient satisfaction rates, healing rates after arthroscopic rotator cuff repair as low as 6% have been reported.[30] However, the relation between structural healing of the rotator cuff and clinical outcomes remains poorly defined. Our study qualitatively describes the clinical results of published cohort studies on arthroscopic repair of rotator cuff tears comparing healed (intact) versus nonhealed repairs, as determined by use of imaging modalities. On the basis of the published cohort studies included in our review, there are several key differences between healed and nonhealed repairs in terms of subjective and objective outcomes. Patients with healed rotator cuff repairs after arthroscopic repair can probably expect better strength (5 of 8 studies, $P < .05$) and possibly better functional outcomes (e.g., 6 of 9 studies with higher Constant scores; $P < .05$). No definitive conclusion, however, can be drawn because of the variability in the studies (i.e., different outcome scales, strength measurements, and rotator cuff tear characteristics). Furthermore, because the studies were not Level I studies, no meta-analysis could be performed to determine whether a true difference exists between healed and nonintact rotator cuff repairs.

Selection Bias

All of the studies included in this systematic review were Level IV cohort studies. There are no Level I, II, or III studies that address this clinical question. A thorough literature search was performed before the review to include every possible published report that met the inclusion criteria. Several studies were excluded at the onset of the review to ensure sufficient homogeneity between comparison groups to limit the potential for selection bias. To be included in this review, studies needed to compare rotator cuff integrity after arthroscopic repair with clinical outcomes, without the bias of other variables. Specifically, studies that compared outcomes or rotator cuff integrity between arthroscopic and open repairs[2,24,25] or used other variables such as double- versus single-row repair[33-35] were excluded from the study.

Given the nature of the study measuring postoperative results (healed *v* nonhealed), there is bound to be some variability in patient demographics between the 2 groups. If the 2 groups could be chosen preoperatively, uniformity in the cohorts could be controlled. For example, age was shown to be statistically different in those patients who had a nonhealed repair after arthroscopic rotator cuff repair in several of the studies.[37,38,40,41,45-47] In addition, it is known that rotator cuff tear size affects the healing rates in open, mini-open, or arthroscopic repairs.[2,49-51] Several of the authors of the articles included in this study corroborated the fact that tear size did affect the integrity of the rotator cuff repair.[36,40,43,46] The differences in these demographics could lead to a selection bias altering the healing rates of arthroscopic rotator cuff repairs

and may also affect clinical outcomes in these patients.

Performance Bias

Although all rotator cuff repairs analyzed in this review were performed arthroscopically by use of suture anchors, the technique inevitably varied among the surgeons in the different reports. Several surgeons reported the use of double-row techniques, whereas others used single-row techniques but varied between medial and lateral placement. Furthermore, surgeons in 2 of the reports used transosseous repairs instead of single- or double-row techniques. Finally, 1 of the articles described a multicenter study with several different surgeons, each using different repair techniques, thus providing a source of variability in the results.[48] However, because we were interested in a single postoperative variable, radiographic healing of the rotator cuff, and specific clinical outcomes related to this variable, the influence of surgical technique should be limited. Surgical technique may influence healing rates after repair, but this should have limited influence on clinical outcomes if the tear is healed versus a persistent tear.

Performance bias plays a role when an unequal number of concomitant procedures are performed in one group versus the other. Concomitant procedures performed with the rotator cuff repair varied among the different reports, providing a potential source of performance bias. However, this bias was likely limited because of the homogeneity between cohorts as determined by the inclusion and exclusion criteria of the review, with most series performing similar numbers of concomitant procedures in each group. For example, subacromial decompression was performed in all or nearly all patients in 8 of the 13 studies (62%). However, no study broke down the number of concomitant procedures based on integrity. Rehabilitation protocol is another likely variable that can influence performance bias, but the same protocol was used in each group in the respective studies.

Exclusion Bias

Four studies in the final analysis had less than 80% follow-up (range, 66% to 78%), which helps to minimize exclusion bias in this review. The range of follow-up among the other 9 studies was 80% to 100%, with 4 studies achieving 100% follow-up. The overall effective follow-up for all 13 studies was 76%, which is of concern because most peer-reviewed journals require greater than 80% follow-up for publication.

Detection Bias

There were a large variety of outcome scoring measurements used throughout the studies. Each study used either the Constant score, UCLA score, ASES score, SST score, Pennsylvania Shoulder Score, and/or L'Insalata score. All of these outcome scales have been proven as valid shoulder-specific instruments.[10,12,14,15,52,53] Regardless of the outcome measure, each of the studies showed significant differences (improvement) when comparing preoperative and postoperative scores, thus minimizing detection bias. With regard to strength measurements, although only 8 of the studies included in this review provided strength measurements as an outcome, 5 of these studies (63%) reported a significant increase in strength in the forward elevation plane among patients with a healed repair compared with a nonhealed repair.[40,43,45,48] In addition, 2 articles reported a significant increase in strength in the external rotation plane in patients with healed repairs.[36,46]

With regard to functional outcome, there were a wide variety of outcomes reported. The Constant score was the most frequently used outcome scale, with 9 of the 13 studies using this outcome scale. Six of the nine studies did find a significant difference in Constant scores between healed and nonhealed rotator cuff repairs. There are 4 components of the Constant score: mobility, activity, strength, and pain. Large gains in one of the components could lead to an overall finding of statistical significance whereas the other three components would not reach statistical significance if measured alone. This is particularly important because one component of the Constant score is related to strength. Only two of the studies broke the Constant scores down and used statistical analysis to determine whether each component measured was significant. This example shows the detection bias possible when outcome scales are used in total and not broken into their respective components.

The varied findings of improved strength, pain, and range of motion in some studies but not others raise the concern of whether healing after arthroscopic rotator cuff truly leads to an improved clinical outcome. All of the published studies on rotator cuff integrity after repair have been Level IV studies, leading to controversial findings. As shown in this study, some studies have reported a difference in healed tendons in terms of subjective outcome, range of motion, and strength compared with patients with nonhealed ten-

dons; however, other studies have not shown a difference. Longer-term prospective studies are needed to determine the relation between tendon healing and clinical outcome. Furthermore, specific factors such as muscle quality, fatty infiltration, size of recurrent defect, and which tendons are involved all may affect the clinical outcome in patients with recurrent defects and require further study.

Strengths

There are many strengths of this study related to the design resulting in homogeneity between the study groups. Because of the strict inclusion and exclusion criteria, only studies that compared healed versus nonhealed arthroscopic rotator cuff repairs were included in the study, and each of these studies ensured homogeneity between the 2 study groups to the extent possible. In addition, with respect to each individual study, the concomitant procedures, repair techniques, rehabilitation protocols, and outcome measurement instruments were consistent between the healed and nonhealed groups. Although 35 studies were initially deemed appropriate for review, 21 of these were excluded from the study because they may have introduced more bias, despite increasing the number of overall patients.

Limitations

There are a number of limitations to this study. In addition to the lack of Levels I, II, and III studies, the major limitation of this study is the assumption that all radiologic modalities measure what they purport to measure—the presence or absence of a persistent rotator cuff tear after repair. There were several modalities used in this study to determine rotator cuff integrity. Each of these studies has the ability to detect rotator cuffs, but none has been shown to have 100% sensitivity or specificity. Reported sensitivities vary from 83% to 99% depending upon the study.[54-56] Given the inherent limitations of MRI, ultrasound, and CTA, there will be some false-positive repairs and false-negative tears. Despite this limitation, all of the authors of the included studies were very proficient in the modality they chose to determine the presence of a rotator cuff tear after arthroscopic repair.

CONCLUSIONS

This systematic review suggests that some important differences in clinical outcomes likely exist between patients with healed and nonhealed rotator cuff repairs; however, the results of this systematic review cannot definitely state that the results for healed rotator cuff repairs are better based on any of the clinical outcomes because of the mixed results in the studies included. With regard to the primary clinical outcome measures used in each study, 7 of 13 studies found a statistical difference favoring intact rotator cuff repairs. Furthermore, statistical improvement in patients who had an intact cuff at follow-up was seen in Constant scores in 6 of 9 studies, UCLA scores in 1 of 2 studies, ASES scores in 0 of 3 studies, and SST scores in 0 of 2 studies. Significantly increased range of motion in forward elevation was seen in 2 of 5 studies, and increased strength in forward elevation was seen in 5 of 8 studies. Longer-term studies with identical repair techniques and imaging modalities are needed to provide more conclusive information on the association between healing (as determined by imaging) and clinical outcomes after arthroscopic rotator cuff repairs. In addition, factors predictive of outcome in patients with recurrent tears after rotator cuff repair need to be identified.

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