



Arthroscopic rotator cuff repair: magnetic resonance arthrogram assessment of tendon healing

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Background: Many poor outcomes after arthroscopic rotator cuff (RC) repair relate to failure of tendon healing. The purposes of this study were to provide a better understanding of the magnetic resonance arthrography (MRA) characteristics of the RC tendon repair site after arthroscopic RC repair and to examine how these findings influence patient-reported outcome measures (PROMs) and the presence of persistent symptoms.

Methods: We reviewed 48 shoulders (13 female and 35 male patients; average age, 53.8 years) at a minimum of 6 months (average, 11.4 months) after arthroscopic RC repair (average tear size, 2.2 cm). All patients completed PROMs and underwent MRA assessment. Detailed analysis of the RC repair site was undertaken, with findings correlated with clinical outcomes and PROMs.

Results: The average preoperative American Shoulder and Elbow Surgeons (ASES) score of 39.5 improved to 92.8 ($P < .001$). All but 6 patients (87.5%) had increased signal intensity of the involved tendon, with interstitial splits and/or delamination in 65.6%. These changes had no effect on PROMs or patient satisfaction. Significant partial-thickness tears (>50%) were observed in 7 patients (14.6%), with no effect on outcomes (average ASES score of 95.2 and satisfaction score of 9). There were 2 recurrent full-thickness tears (4.2%), and 4 patients (8.3%) had a failure in continuity. The average ASES score in these 6 cases of failure was 76 ($P < .001$).

Conclusions: Structural abnormalities on MRA are common after RC repair but do not always result in clinical failure. However, our results suggest that an ASES score of less than 80 may be useful when considering postoperative imaging, especially in a patient with ongoing pain more than 6 months after surgery.

Level of evidence: Level IV; Case-Control Design; Diagnostic Study

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Keywords: Arthroscopic; rotator cuff repair; MR arthrography; failure in continuity; patient-reported outcome measures; rotator cuff repair failure

The New Zealand Health and Disability Ethics Committee deemed this study exempt from IRB approval.

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Little is still known about the basic biology of rotator cuff (RC) healing, and failure of healing after RC repair continues to be of concern. Approximately 30% of RC repairs are reported to fail, with failure rates as high as 90% in patients with large chronic tears.^{3,5,18,22,44} Numerous studies have looked at various prognostic factors and

patient-related risk factors that may influence RC healing.^{7,17,39,45,49,56,62} However, the determination of when healing has occurred and exactly what the repair site looks like remains difficult to assess. None of the existing imaging modalities are ideal in this regard, with magnetic resonance imaging (MRI) the most widely used.⁴¹ Currently, the 5-type MRI classification system reported by Sugaya et al⁶⁷ in 2007 remains the most common method to assess the RC repair site.

A primate model of RC repair showed that a significant proportion of Sharpey fibers start to reconstitute at 3 months, with maturation seen at 4 months.⁶⁵ In human shoulders, it is believed that ultimate failure strength of the repaired tendon is usually reached by 6 months after repair,^{23,73} although tendon maturation continues to take place and muscle strength will not be fully recovered at this time.⁴² Retears, or failure of the tendon to heal, usually occur soon after surgery and often within the first 3 to 6 months.^{32,37,51} Therefore, 6 months is thought sufficient to assess the integrity of a repaired RC tendon. After this period, although the functional status will continue to improve, the structural status of the tendon will tend to remain unchanged.^{8,42}

The normal graded transition of the fibrocartilaginous RC insertion is not re-created after the tendon is surgically reattached to the bone. Instead, mechanically inferior and disorganized scar tissue forms at the repair site.⁷⁴ Consequently, the enthesis never reaches mechanical properties comparable to those of the native RC tendon.³³ The appearance of the RC tendon repair site when assessed by larger field-strength (3.0-T) MRI magnets in combination with contrast agents is poorly understood. The purposes of this study were to provide a better understanding of the magnetic resonance arthrography (MRA) characteristics of the RC tendon repair site after arthroscopic RC repair and to examine how these findings influence patient-reported outcome measures (PROMs) and the presence of persistent symptoms. Our hypothesis was that there would be no correlation between the MRA appearance of the repaired tendon and any of the PROMs.

Materials and methods

We performed a level IV retrospective study of 51 shoulders in 51 patients who underwent arthroscopic double-row suture-bridge RC repair of a full-thickness posterosuperior RC tear. All surgical procedures were performed by the author over a 24-month period using a standardized arthroscopic surgical technique, using 3.5-mm polyetheretherketone (PEEK) SwiveLock anchors (Arthrex, Naples, FL, USA) for the medial row and 4.75-mm biocomposite SwiveLock anchors (Arthrex) for the lateral row. The medial-row sutures were not tied but were “bridged” directly to the lateral-row anchors and secured with individual tensioning of each suture limb (Fig. 1).

Patients were included in the study if they met the selection criteria. The primary criterion was a repairable full-thickness tear

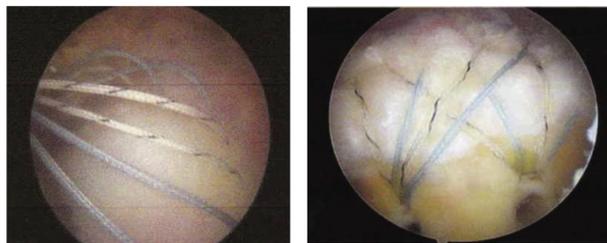


Figure 1 Repair technique showing medial-row sutures being bridged directly to lateral-row anchors without being tied.

limited to the posterosuperior RC, and both traumatic and atraumatic tears were included. Patients who had undergone concomitant procedures were included only if it was deemed that the addition of such procedures would not affect either the interpretation of the MRA images or the outcome on the various PROMs. The concomitant arthroscopic procedures performed are outlined in Table I. Patients were excluded if their tear was not fully repairable, if the operation was a revision procedure, or if more significant (or open) concomitant procedures were required (eg, labral repair, larger tears of the subscapularis, or cartilage surgery).

All surgical procedures were performed with patients in the beach-chair position under general anesthesia supplemented with an interscalene regional nerve block. The average tear size was 2.2 cm, with a range from 1 to 3.5 cm. An average of 2 medial-row and 2 lateral-row anchors were used for the repair. An incomplete (medialized) reduction of the tendon was undertaken in 6 patients to avoid over-tensioning of the repair. All patients as part of their procedures underwent a subacromial bursectomy and limited acromioplasty to remove any spurs present.

All patients had previously undergone a standardized preoperative clinical and radiologic assessment of the involved shoulder and had completed the American Shoulder and Elbow Surgeons (ASES) Assessment Form score.⁵⁹ At a minimum of 6 months after surgery, all patients were invited to return to undergo clinical assessment of the shoulder and to complete various PROMs, including the ASES Assessment Form, Simple Shoulder Test (SST),⁴⁶ and patient satisfaction rating. In addition, all patients were invited to undergo a standardized MRA assessment of their shoulder, with attention being directed to the RC repair site. Tear retraction, muscle atrophy, and fatty infiltration were not assessed

Table I Study patient demographic characteristics with details of concomitant procedures performed

Variable	n (%) or mean (range) (N = 48)
Sex	
Male	35 (72.9)
Female	13 (27.1)
Age, yr	53.8 (32-71)
Dominant arm	30 (62.5)
Concomitant procedure	
Upper subscapularis repair	18 (37.5)
Biceps tenotomy	4 (8.3)
Biceps tenodesis	8 (16.7)
Acromioclavicular joint resection	7 (14.6)

as part of the study as all tears were fully repairable. All MRA scans were undertaken using the same 3.0-T magnet (Philips Healthcare, Best, The Netherlands) and scanning protocol, with independent assessment of the images undertaken by an experienced musculoskeletal radiologist. Detailed assessment of the involved RC tendon and repair site was undertaken, with findings correlated with clinical outcomes and PROMs.

Three patients declined to be involved in the study, leaving 48 patients (94.1%) who underwent a clinical assessment, completed PROMs, and underwent a postoperative MRA scan. The median time to MRA assessment was 10.0 months (range, 6-30 months) after surgery. There were 13 female and 35 male patients, with an average age of 53.8 years (range, 32-71 years). In 30 patients (62.5%), the dominant arm was involved.

Standard descriptive statistics were used to describe the preoperative and postoperative clinical and demographic features of the sample. These included means, medians, ranges, frequencies, and percentages as appropriate. The changes in ASES scores from preoperatively to postoperatively were analyzed using a paired *t* test.

Results

The average preoperative ASES score was 39.5 (range, 13.3-86.6). This improved after surgery to 92.1 (range, 61.7-100) at latest review ($P < .001$). The average postoperative SST score was 90.3 (range, 45.4-100). All but 1 patient was satisfied and would undergo the procedure again, with an average patient satisfaction score of 9 (range, 4-10). The patient who said she would not undergo the procedure again was a 69-year-old woman who underwent repair of a large 3.5-cm retracted RC tear with delamination. On follow-up MRA, a type II (medial-row) failure of the RC repair was noted,⁷¹ and the patient had an ASES score of 61.7 and a satisfaction score of 6.

Patient age was negatively associated with improvement in the ASES score, with older patients having smaller increases overall ($P = .027$). A negative correlation was found between the preoperative ASES score and change in score, whereby lower preoperative scores improved more ($P < .001$). However, a positive correlation was noted between the preoperative ASES score and the postoperative ASES score ($P = .009$) and SST score ($P = .003$), in that the higher the preoperative scores, the higher the postoperative scores. These thresholds applied regardless of patient and tear characteristics.

Leakage of contrast into the subacromial space was observed in 54.2% of the 48 study patients. When present, this allowed for a better assessment of the bursal surface of the RC, helping to distinguish between postoperative inflammation and/or scarring and recurrent partial (bursal-surface) tears. Signal changes were observed around the suture anchors in 15 cases (31.3%). These signal changes occurred around both the medial (polyetheretherketone)-row and lateral (biocomposite)-row anchors, and there was no difference in the incidence

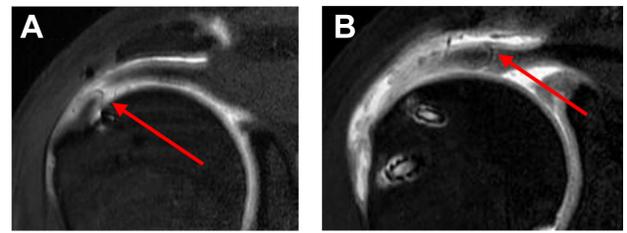


Figure 2 Suture passage (→) through the rotator cuff can be helpful in the assessment of rotator cuff repair integrity: intact repair (A) vs. failure in continuity (B).

between the 2 rows. The presence of these changes had no influence on clinical outcomes or PROMs ($P = .266$). In many patients, the repair sutures were clearly visible. Their position as they traversed the RC tendon was helpful in determining repair integrity (Fig. 2), but because they were not visible on all MRA scans, their presence could not be quantified.

Of the 48 study patients, 42 (87.5%) had increased (intermediate) signal intensity of their tendons on T2-weighted fat-saturated images. These signal changes were more pronounced on the scans taken at earlier time points but were also seen on scans taken 30 months after surgery. With a median time to MRA of 10 months, the limited number of scans at later time points did not allow quantification or statistical analysis of the signal changes to be performed. Minor interstitial splits and/or delamination was observed in 65.6% of patients (Fig. 3). The presence of the aforementioned changes had no effect on PROMs or patient satisfaction. The average ASES score in these 42 patients was 95.7 ($P < .001$).

In comparison with the patient's preoperative imaging, RC tendon thickness was reduced in 8 patients (16.7%). A failure in continuity of the repair was diagnosed in 4 of these patients.⁴⁸ In the remaining 4 patients, the tendon was thinned but otherwise normal with an intact repair.

Significant partial-thickness RC tearing (footprint coverage < 50%) was observed in 7 patients (14.6%). In 3 of these patients (42.9%), the tendon repair had been deliberately medialized at the time of surgery to avoid over-tensioning. Although 1 patient underwent revision RC repair surgery at 11 months for persistent shoulder pain and weakness, the average ASES score in this group was 95.2,

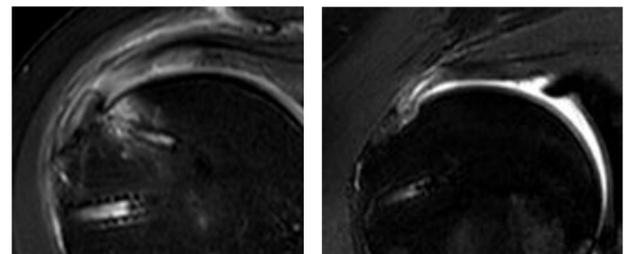


Figure 3 Increased signal intensity, minor splits, and delamination are very common observations on MRA after rotator cuff repair.

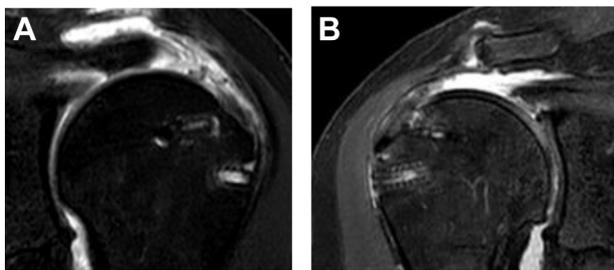


Figure 4 Example of full-thickness type I failure (A) and type II failure (B).

with an average satisfaction score of 9. The patient who underwent revision surgery had an ASES score of 81.7 and a satisfaction score of 7.

We observed 2 recurrent full-thickness RC tears (4.2%). One of these was a type I failure (from the insertion site)⁶ that was observed in a female patient aged 51 years who underwent repair of a 2-cm L-shaped tear. At latest review, her ASES score was 100, with a satisfaction score of 10. The other failure was a type II (medial-row) failure that occurred in a female patient aged 69 years with a large 3.5-cm retracted tear with delamination (Fig. 4). Her postoperative ASES score was 61.7, with a satisfaction score of 6.

Failure in continuity was observed in 4 patients (8.3%) (Fig. 5), comprising 2 male and 2 female patients with an average age of 58.75 years and an average tear size of 2.5 cm. At a mean of 11.75 months postoperatively, the average ASES score in these patients was 71.3 (range, 61.7-80), the average function score was 7 (range, 6-8), and the average satisfaction score was 6 (range, 4-8). One patient underwent revision at 10 months for persistent pain and poor function (high-dose prednisone for Crohn disease had been started 2 months after RC repair). All other patients had not undergone revision to date but had continued to have some degree of persisting pain and weakness at latest review.

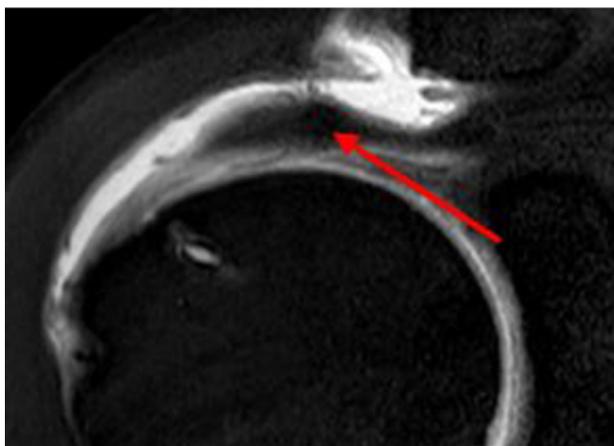


Figure 5 Example of rotator cuff repair failure in continuity. The medialized medial-row suture (→) and medialized musculotendinous junction should be noted.

Comparisons between the 6 failures in our series and all other patients were significant for larger average tear size ($P = .043$); female sex ($P = .038$); and lower postoperative PROM scores including ASES, SST, and satisfaction scores (all $P < .001$). The ASES scores in our patients with a full-thickness failure or failure in continuity not only were statistically worse than those in patients with an intact or partially torn RC repair but also were clinically inferior (average ASES score of 71.3 vs. 95.7 with failures excluded). Only 1 patient in this group (type I full-thickness failure) had an ASES score above 80. Patient age ($P = .122$), tear reduction ($P = .322$), and whether additional procedures were undertaken had no influence on repair failure.

Discussion

Arthroscopic RC repair has become the most common surgical treatment method to address symptomatic RC tears of all sizes. Techniques have evolved rapidly over the last 15 years, but controversy remains regarding the best repair method. However, when tendon quality is good and there is a high biological potential for the tendon to heal, arthroscopic double-row repair techniques that optimize coverage of the RC footprint are generally recommended, especially for larger tears.^{31,52,60} Many studies have shown good clinical results and patient satisfaction after arthroscopic RC repair.^{3,11,16} PROMs usually improve significantly from baseline to 1 year and then continue to improve for up to 2 years, as do improvements in range of motion and strength.⁵⁵ Our study is consistent with these reports, with the average preoperative ASES score of 39.5 (range, 13.3-86.6) improving to 92.8 (range, 61.7-100) at latest review ($P < .001$).

Early structural failure after RC repair does not always result in clinical failure,^{5,35,54,61} with prior reports suggesting that it cannot be accurately predicted using outcome measures alone.^{13,14} Given that retears (failure to heal) tend to occur soon after surgery (usually within the first 3-6 months),^{37,41} if a patient has ongoing pain more than 6 months after RC repair, it is worth considering imaging to assess repair integrity. Although ongoing functional improvements may still be expected, if a patient has pain and lacks RC healing at 6 months, his or her pain will typically persist.¹⁰ Repair-site integrity at 6 months has also been reported to be an important predictor of long-term clinical outcomes.^{10,41}

Unfortunately, none of the existing imaging modalities are ideal for postoperative evaluation of the RC. Ultrasound examination is reasonable when a recurrent full-thickness tear is suspected,¹² but the sensitivity is lower than that of MRI and the specificity and predictive values of ultrasound are very much dependent on the equipment and experience of the operator.^{9,53} With larger field-strength (3.0-T) magnets, better use of contrast agents, and improved magnetic

resonance sequencing techniques (to reduce image degradation due to surgical distortions and implant-related artifacts), improved interpretation of the changes seen after RC repair is now possible.² This has resulted in MRI and MRA becoming invaluable in the investigation of the painful postoperative shoulder, especially in relation to the RC. We chose MRA over MRI primarily because we believed that this would give a better overall assessment of the RC repair site. MRA has been shown to have a greater accuracy and sensitivity for the detection of partial-thickness articular-surface RC tears,⁴⁷ and the addition of contrast also allows for a better assessment of pathologic conditions of the tendon.

The evaluation of postoperative MRI and MRA scans is made difficult by the normal leakage of fluid and/or contrast into the subacromial space. This does not represent a low rate of tendon-to-bone healing but rather is due to opening of the rotator interval during the arthroscopic procedure and/or due to the passage of instrumentation and sutures through the RC tendon.⁵⁰ Passage of contrast into the subacromial space can also occur via suture tracks, which do not represent pinhole-size recurrent full-thickness defects. Fluid in the subacromial bursa and “bursitis-like” abnormalities are common after RC repair, and in some patients, these changes may persist for many years.¹ Some osteolysis around the suture anchors can also be expected—usually as the result of the mechanical force of and focal necrosis from anchor insertion. These changes eventually stabilize and undergo replacement with bone,²⁵ although cystic collections around bio-anchors can occasionally be seen.⁵⁷

Only a small number of reattached tendons generate a normal magnetic resonance signal (12.5% in our series), and although these signal changes tend to resolve over the first 18 to 24 months,⁴² some may persist for years.^{14,66} Many of these signal changes are likely due to previously present degeneration (tendinopathy) within the torn RC tendon and/or due to the normal phases of tendon-to-bone healing with subsequent remodeling and maturation.⁶⁶ Recent reports have suggested that the degree of tendinopathy does not correlate with RC healing potential or patient outcomes.⁶⁴

Signal intensity changes can therefore be considered part of the spectrum of the normal postoperative appearances of a repaired RC, especially as they have no influence on clinical outcomes or PROMs. The presence of these signal changes can mean that intrarater and inter-rater agreement for healing assessment after RC repair is higher at later time points than at 6 months,^{29,56} and it is therefore not prudent to consider an RC repair as failed according to increased signal intensity alone. A recent 10-year multicenter clinical and MRI evaluation reported that even at 10 years after repair of isolated supraspinatus tears, only 12% of the healed tendons had a perfect tendon appearance (Sugaya type I).¹¹

RC degeneration is common in older individuals in whom the normally compact and well-organized collagen fibers become replaced by mucoid and eosinophilic material. Small splits and surface fibrillations are not uncommon, and many RC tears are accompanied by intratendinous splits and areas of delamination. The incidence of delaminated RC tears in previous reports ranged from 38% to 82%,^{3,65} with posterior delamination being more common. Many of these intrasubstance changes and areas of delamination do not heal after RC repair,^{28,36} a finding we observed in 65.6% of the RC repairs in our series. Gwak et al²⁸ speculated that tension mismatch between the layers of the RC after repair potentially leads to partial healing and persistence of the delamination. The presence of these intratendinous splits and delamination had no effect on PROMs or patient satisfaction scores in our series (if we eliminate our 6 failures, the average ASES score was 95.7).

One must also be cautious about calling all irregularities on the surface of the repaired RC “partial-thickness tears.”⁷⁰ To diagnose a true partial-thickness tear, there must be disruption with retraction of an RC layer, especially on the articular side, with contrast signal filling the defect. MRA may help to differentiate granulation (fibrovascular) tissue from a fluid-filled gap because granulation tissue will not fill in with contrast (it will have mildly increased signal intensity on T2 images) whereas a tear will. Some authors have suggested that an RC repair is failed if footprint coverage is less than 50%.³ However, this is not a good indicator of surgical failure as inadequate lateral coverage of the tuberosity may indicate partial healing, not a recurrent tear, and it is also dependent on the adequacy of tendon reduction at the time of surgery. In addition, persistent abnormalities in the morphology of the surgically manipulated tendon often occur, making accurate assessment of the footprint difficult. One study using MRA reported that despite adequate healing, none of the repaired RC tendons appeared to be normally inserted on the footprint,⁵⁰ with another study reporting that 20% to 50% of tendons will have a visible tendon defect that may persist for years.²⁶

Our study used footprint coverage of less than 50% to distinguish the presence of a potentially significant partial-thickness RC tear. On the basis of this criterion, a significant partial-thickness defect was observed in 7 patients (14.6%). In 3 of these patients (42.9%), the tendon was deliberately medialized at the time of surgery to avoid over-tensioning the repair. Despite the presence of these defects, the average postoperative ASES score in this group was 95.2, with an average patient satisfaction score of 9. One patient (ASES score, 81.7; satisfaction score, 7) did require revision surgery 11 months after surgery for persistent shoulder pain and weakness, having already undergone disruption of the biceps tenodesis at 9 weeks after surgery because of noncompliance with rehabilitation.

An important observation in studies using both ultrasound and MRI is that healing rates of repaired RC tendons can increase with time.³⁷ This suggests that some defects shown on scans at earlier time points may represent disorganized scar tissue that is functional and can continue to heal and remodel. Good clinical and radiologic outcomes after medialized RC repairs have also been reported.^{24,40} However, there is still concern that with time, some of these significant partial-thickness RC tears may progress.

The most important concern in a patient with post-operative pain and/or poor function is failure of healing and a recurrent full-thickness RC tear. Such failures are often atraumatic and typically occur within the first 6 months. Ultimately, the characteristics associated with successful and unsuccessful results after structural failure of an RC repair are poorly understood.⁴³ However, the concern is that asymptomatic retears in the short term and midterm may progress to larger symptomatic tears requiring revision surgery, which by then may be difficult to revise.⁵⁶ The detection of a full-thickness RC tear by MRI in the post-operative patient uses criteria similar to those used for identifying a native tendon tear. Gaenslen et al²⁰ reported an 84% sensitivity and 91% specificity for MRI in identifying recurrent full-thickness RC tears. The addition of contrast (MRA) improves the identification of these RC retears^{15,58} and may help to differentiate granulation tissue from a fluid-filled gap because granulation tissue will not fill in with contrast whereas a retear will.

There were 2 recurrent full-thickness RC tears in our series (4.2%), both in women (Fig. 4). One occurred at the medial row (type II failure).⁷¹ This mode of failure is unique to transosseous-equivalent and especially suture-bridge RC repair techniques and is thought to relate to tension overload at the medial row, passage of sutures at the musculotendinous junction, strangulation by knot tying at the medial row, and/or compromise in the blood supply from the proximal tissue.³⁸ The primary area of stress concentration on the RC after double-row suture-bridge RC repair is found on the superficial surface of the RC around the sutures of the medial anchor.^{19,63} Excess stress due to over-tensioning of the repair at this site could induce tearing of the repair at the medial row.^{30,71} Larger holes in the RC created by suture-passing instruments or braided suture materials can also be a possible cause of this tearing, as can tying the medial-row sutures, especially when one observes the variability in where these sutures pass through the tendon (Fig. 6).

Failure in continuity describes a process of tendon retraction away from the position of initial fixation without the formation of a recurrent defect. First described by McCarron et al,⁴⁸ it has subsequently received little attention in the literature. Failure in continuity was observed in 4 patients in our series (8.3%) and is likely the result of the repaired tendon pulling through the sutures with subsequent elongation of newly formed reparative tissue and/or

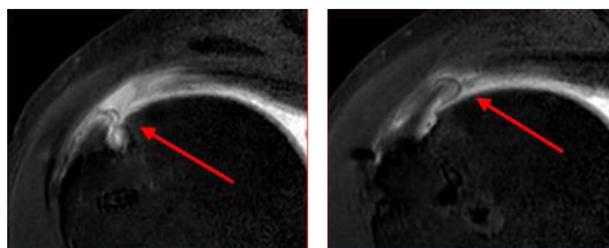


Figure 6 Different MRA image slices in same patient illustrating variability in medial-row suture placement (→) with potential for over-tensioning repair.

elongation of the tendon medial to the repair sutures.⁴⁸ Frequently observed in animal studies in which immobilization of the affected limb is not possible,⁷² it is likely a progressive phenomenon that does not result in a complete disruption of the repair but rather results in an elongation of the tendon with scar tissue. Many studies have supported the theory that tendon healing occurs through a combination of tendon lengthening and muscle elongation.^{68,69} As a result, there is medialization of the musculotendinous junction and a lack of restoration of the normal length-tension relationship of the RC, which functionally has the same effect as a recurrent full-thickness defect (Fig. 5). This may explain, at least in part, why painful weakness of the RC and progression of muscle changes can occur even with an intact repair.^{27,34}

It is important to be cautious of radiology reports suggesting that an RC repair is “thinned but intact.” Mean tendon thickness should remain stable with time and must be compared with preoperative tendon thickness to be a useful measure.¹⁴ It is important to differentiate thinning of the RC due to a chronic tendon tear with poor-quality tissue, tendon compression owing to the RC repair technique used, and tendon retraction without a recurrent defect (failure in continuity). Tendon thickness was reduced in 8 patients in our series (16.7%), 4 of whom were identified as having a failure in continuity and 4 of whom had tendons that were thinned but otherwise appeared normal. In the 4 patients with failure in continuity, the average ASES score was 71.3 and the average satisfaction score was 7 ($P < .001$).

A recent study reported that the minimal clinically important difference in the ASES score for patients with full-thickness RC tears was 21.9 when using an anchor-based method and was 26.9 and 17.9 when using a distribution-based (standard deviation) approach.²¹ By use of these criteria, the ASES scores in our patients with a full-thickness failure or failure in continuity not only were statistically worse than those in patients with an intact or partially torn RC repair ($P < .001$) but also were clinically inferior (average ASES score of 71.3 vs. 95.7 with failures excluded). Only 1 patient with a type I full-thickness failure had an ASES score above 80. Patient satisfaction and SST scores were also significantly worse in this group ($P < .001$).

Table II Proposed new MRI classification system to aid in assessment of postoperative RC repair integrity

Grade	Description
I	Sufficient thickness with or without high signal intensity within tendon
II	Significant partial-thickness (>50%) discontinuity
III	Full-thickness type I failure
IV	Full-thickness type II failure
V	Failure in continuity

MRI, magnetic resonance imaging; *RC*, rotator cuff.

The aims of our study were to improve our understanding of the changes seen on MRA after RC repair and to better understand their clinical significance. This may allow a better understanding of the etiology of persistent symptoms and poor patient outcomes. The results of this study confirm that PROMs cannot predict the presence of partial-thickness (>50%) RC repair failures. However, when one considers full-thickness RC repair failures and failure in continuity, comparisons between the 6 failures in our series and all other patients were significant for larger average tear size ($P = .043$); female sex ($P = .038$); and lower postoperative PROMs including ASES, SST, and satisfaction scores (all $P < .001$). In addition, when one considers who may benefit from postoperative imaging to assess for repair failure after arthroscopic RC repair, an ASES score of less than 80 may prove a useful guide.

The United Kingdom Rotator Cuff Surgery (UKUFF) randomised trial performed MRI or high-definition ultrasound imaging at 12 months after RC repair and used the Oxford Shoulder Score (OSS) as the primary outcome measure.⁴ This was a large, multicenter, randomized controlled trial performed to compare the effectiveness of open vs. arthroscopic RC repair. Although the retear rates were high, they were similar for both groups (46.4% for arthroscopic surgery vs. 38.6% for open surgery), and the OSS improved in both repair groups. The mean difference in the OSS at 2 years between healed tears, retears, and irreparable tears was approximately 3 points for each, with healed repairs having the best clinical outcomes and irreparable tears having the worst. These results support the findings of our study.

A new MRI classification system to aid in patient management and the reporting of clinical and radiographic failure after arthroscopic RC repair is provided in Table II. However, it is important to remember that a lack of healing at 6 months does not always result in clinical failure, and imaging findings should be interpreted with caution and correlated with the clinical presentation.

This study has some inherent limitations. First, it was a single-surgeon series, which might limit the ability to

broadly extrapolate the results but does limit the number of confounding variables that can arise from multiple-surgeon studies. Second, many different surgical techniques are currently available when performing an arthroscopic RC repair. The technique undertaken in this study provides only 1 example, and the clinical and structural results may therefore differ between different surgeons and different repair techniques. The surgeon is a shoulder fellowship-trained surgeon and had significant experience in arthroscopic RC repair before undertaking this study, and the repairs were standardized for all patients. However, the results should still be interpreted with caution.

Third, this was a retrospective series, and the small number of patients limits the ability to perform extensive subgroup analysis and examine all potential confounding variables. However, this was a consecutive series of patients with 94.1% of patients agreeing to be involved in the study, and all MRA assessments were performed using the same 3.0-T MRI magnet. Fourth, a minimum 6-month time point was selected to undertake the MRA assessments, and the appearance of the repaired RC may be altered at later time points. The timing of the postoperative scans ranged from 6 to 30 months after surgery rather than a single time point, which may have resulted in substantial variability in tendon appearance depending on when a scan was undertaken. However, most studies agree that structural status remains unchanged after the 6-month time point, and in some patients, the MRI appearance of the RC repair will likely improve. Finally, no comparative imaging or second-look arthroscopy was undertaken, which makes our study primarily descriptive and precluded the establishment of values for the various test characteristics (sensitivity, specificity, and predictive values) of MRA. Further longer-term follow-up studies are required to investigate changes in PROMs and the MRA appearance of the repaired RC tendon at later time points.

Conclusion

Structural abnormalities on MRA are common after RC repair but do not always result in clinical failure, making it important not to interpret all irregularities on MRA as repair failure, especially at early time points. Many of these changes can be considered part of the normal healing process of a repaired RC. However, if a patient has pain and poor function more than 6 months after RC repair, then imaging should be considered, and our results suggest that an ASES score of less than 80 may be useful when considering in which patients to perform MRA. Ultimately, improved interpretation of the RC repair site may lead to a better understanding of the influence of different repair techniques and

rehabilitation protocols and a better evaluation of future strategies to mechanically and biologically augment RC repairs.

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Disclaimer

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