J Shoulder Elbow Surg (2010) 19, 1210-1217

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Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Repair results of 2-tendon rotator cuff tears utilizing the transosseous equivalent technique

Paul M. Sethi, MD[a,*], Benjamin C. Noonan, MD[b], James Cunningham, MD[a], Evan Shreck[a], Seth Miller, MD[a]

[a]*ONS Foundation for Clinical Research and Education, Greenwich, CT, USA*
[b]*Department of Orthopaedics, Yale University, New Haven, CT, USA*

Background: The purpose of this study was to examine the healing rate of 2-tendon rotator cuff tears repaired by the use of a transosseous-equivalent (TOE) suture bridge technique.
Materials and methods: Forty-three patients with combined supraspinatus and infraspinatus tendon tears underwent arthroscopic repair using TOE technique. Forty of these patients were then evaluated by MRI and clinical exam at a minimum of 1-year follow-up to determine the rate of healing of the repair and clinical outcomes associated with healing.
Results: Eighty-three percent of the repairs demonstrated intact rotator cuff repairs at a mean of 16 months post-op. Larger tears (3.5 vs 2.8 cm) were associated with failure ($P = .01$), as was more advanced fatty infiltration (Goutallier 1.3 vs 0.3, $P = .01$). Age was not different between intact and nonintact tendons. Strength was the only clinical finding that differed between intact and nonintact tendons.
Conclusion: Two-tendon tears of the rotator cuff can heal at a high rate with the use of TOE suture bridge repair technique. Furthermore, tear size and Goutallier grading were negatively correlated with postoperative healing. The incremental improvement in the rate of observed rotator cuff healing still does not translate to statistical differences in the objective shoulder scoring systems.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Rotator cuff; arthroscopic repair; double-row; transosseous-equivalent

Rotator cuff surgery has experienced numerous advances over the past decade yielding ultra-strong implants, suture anchors, and suture material. Surgical repair, performed arthroscopically or open, provides a variable (24-94%)[24] rate of healing.[4,12] While most studies have shown improved clinical outcomes after repair, patients with failure of tendon healing to bone demonstrate decreased postoperative strength.[1,23] As the tear size gets larger, retear, or failure of healing occurs at higher rates.[12,18] Nho et al examined the results of rotator cuff repair. The majority if failures (74%) were two tendon tears.[17] Galatz et al reported retears in 17 out of 18 patients who underwent arthroscopic repair for large and massive (>2cm in the transverse dimension) RTC tears when evaluated by US at a minimum of 1-year follow-up.[12] In an effort to improve the rotator cuff healing rates, Park et al[21] described a transosseous-equivalent suture bridge (TOE) that uses multiple linked anchor points both medially and laterally to provide fixation, as well as

IRB approval: Greenwich Hospital IRB # 2007006.

*Reprint requests: Paul M Sethi, MD, 6 Greenwich Office Park, Greenwich, CT 06830.
E-mail address: Sethi@onsmd.com (P.M. Sethi).

1058-2746/$ - see front matter © 2010 Journal of Shoulder and Elbow Surgery Board of Trustees.
doi:10.1016/j.jse.2010.03.018

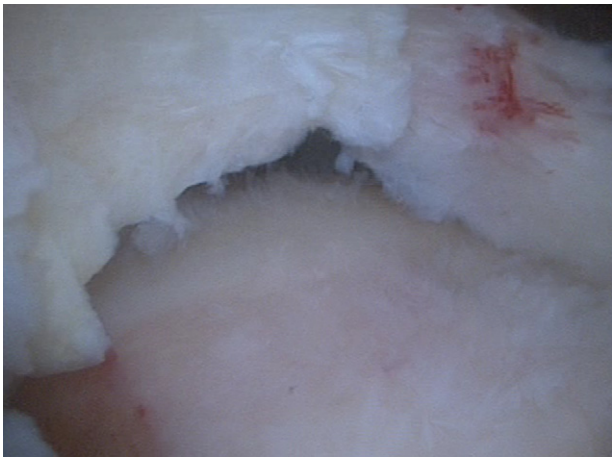

Figure 1 Arthroscopic picture of 2-tendon rotator cuff tear.

Figure 2 Arthroscopic picture of repaired cuff and transosseous equivalent suture bridge technique.

compression to the tendon in an attempt to restore the native footprint.[20]

Our hypothesis was that the biomechanical advantages of the TOE repair would result in a higher rate of healing (clinical exam and MRI) than the current reports on single and traditional double row repairs, specifically in 2-tendon tears of the rotator cuff.

Materials and methods

Between 2006 and 2007, 156 consecutive TOE rotator cuff repairs were identified retrospectively from Orthopaedic & Neurosurgery Specialists PC Shoulder Surgery Registry; 40 of these patients met the criteria for this study. There were 23 men and 17 women with an overall mean age of 61.4 years (range, 34-79). Twenty-seven procedures were performed on the right shoulder, 13 were performed on the left shoulder. All 40 shoulders had both supraspinatus and infraspinatus tears and clinically intact contralateral shoulders as defined by our criteria. During the course of this study, none of the patients had any complaints nor had any interventions performed on their contralateral shoulders.

Twenty-three patients could recall the initiation of their pain/symptoms to a specific traumatic event, prior to which they had no reported symptoms; while 13 patients had chronic shoulder pain and were unable to relate it to a specific event. Nine patients reported initiation of pain following a sporting activity, while 10 patients recalled the onset of symptoms due to a fall. Two patients had chronic pain status post previous rotator cuff repair.

Forty patients returned for MRI evaluation along with subjective and objective clinical evaluations by an attending orthopedic surgeon. Three patients did not return for the study: 1 patient moved out of the area and the other 2 patients did not want to have a repeat MRI. Inclusion criteria for TOE repairs in this study included patients with combined supraspinatus and infraspinatus rotator cuff tears repaired in a spanning fashion with a minimum of 4 suture anchors (Figures 1 and 2). We used a minimum tear length of 2.5 cm in the AP dimension to allow us to exclude smaller single tendon tears. This is based on an anatomical study, which reported a supraspinatus footprint mean AP width of 2.3 cm from Curtis et al,[7] and more recent updates from Mochizuki et al, which describe an even smaller AP (1.2 cm) dimension of the supraspinatus.[16] Even though it appears that Mochizuki et al presented a more accurate description, we chose 2.5 cm as our cutoff for a 2-tendon tear for the purpose of this study to keep consistent with previous studies. This method of describing tear morphology relies more on anatomy than the subjective Deorio classification[8] and does not have the same limitation of fair interobserver reliability.[15] Tear size was determined arthroscopically after subacromial debridement and bursectomy with the use of a calibrated probe. The posterior aspect of the biceps tendon (or bicipital groove when biceps absent) was used as a landmark to measure starting point of the tears. The 3 senior authors performed all repairs. All patients returned for a postoperative MRI, objective scoring and physical examination at a minimum of 1-year post-surgery.

Surgical technique

Surgical technique was similar in all cases and was performed in the beach chair position after interscalene block. Diagnostic arthroscopy and intra-articular evaluation were performed with intra-articular procedures, as indicated in Table I. Attention was then turned to the subacromial space where a bursectomy and subacromial decompression was performed. Acute traumatic tears with no evidence of coracoacromial ligament fraying did not undergo decompression. The rotator cuff was evaluated from multiple portals and the ideal pattern of reduction was determined. If a biceps tenodesis was required, it was performed at this point using a suture anchor below the bicipital groove. The rotator cuff footprint was then denuded of soft tissue and excoriated, leaving behind cortical bone. Two- to 3-suture anchors (5.5 FT; Arthrex, Naples, FL) were placed in the medial row. Sutures were passed through the reduced tendon in a mattress configuration, shuttled through the tendon, and were always tied. After completing the medial row, alternating limbs were linked into the lateral anchors (3.5 Pushlock anchor; Arthrex) and placed into the tuberosity.

Table I Associated procedures

Associated procedures	Number performed
Subacromial decompression	36
Distal clavicle resection	6
Labral debridement	23
Biceps tenodesis	5
Biceps tenotomy	4
Biceps debridement	5
Subscapularis repair	4

Postoperatively, all patients were placed in a sling (Donjoy Ultrasling) and had a cooling pad placed on the shoulder (Donjoy Iceman). Pendulum exercises were initiated on postoperative day one and the sling was worn for 6 weeks. Formal physical therapy was initiated at 6 weeks postoperative and strengthening was emphasized at postoperative week 12.

Clinical evaluation

Postoperative clinical evaluations were performed on all patients and scores were obtained by an attending surgeon. Postoperative data were collected to determine the ROWE, American Shoulder and Elbow Surgeons (ASES), and the Simple Shoulder Test (SST) scores. Active abduction, seated active flexion, and external range of motion were also evaluated using a goniometer.

MRI evaluation

Magnetic resonance imaging studies were performed both preoperatively and postoperatively. The postoperative studies were performed on a single machine at our institution at a minimum of 1-year post-surgery. All postoperative MRI studies were performed on a 1.5-T scanner with the following sequences: proton-density fat-saturation T1-weighted and T2-weighted in the oblique coronal plane, T1-weighted in the axial plane, and T1 and T2-weighted in the oblique sagittal plane. The grade of fatty atrophy of the supraspinatus and infraspinatus muscle belly was assessed according to the classification system of Goutallier et al, using T1 weighted images at the level of the scapular spine.[13] In this system, fatty infiltration in relation to native muscle is ranked as follows: (0) no intramuscular fat (1) some fatty streaks, (2) fat less extensive than muscle, (3) fat equal to muscle, (4) fat more extensive than muscle. The original system was based on CT images; however, it can also be used with MRI.[11,25] Each postoperative study was independently read and interpreted by a musculoskeletal radiologist and 2 orthopedic surgeons. Failure of healing on MRI scan was defined by the persistence of any sized full thickness defect on the postoperative MRI.

Table II Clinical characteristics of intact vs nonintact repairs

Variable	Intact mean (SD)	Nonintact mean (SD)	*P* value*
Age	60.5 (±11.78)	65.3 (±6.58)	.31
Preoperative tear size (cm)	2.8 (±0.7)	3.5 (±0.6)	.01†
Goutallier classification	0.27 (±0.57)	1.3 (±1.15)	.01†

* Value for the difference.
† Significant value ($P < .05$).

Statistical analysis

Clinical outcomes for the intact and failed rotator cuff repairs, as well as range of motion, were compared using 2-tailed *t* tests. Statistical significance was assumed if the *P* value was less than or equal to .05. SPSS software was used in the calculation of descriptive statistics (SPSS 16.0, Chicago, IL).

Results

Mean age of the patients with intact rotator cuffs was 60.5 years (SD, ±11.78) compared to 65.3 years (SD, ±6.58) for failed ($P = .31$) (Table II).

MRI results

The mean time from the preoperative MRI to surgery was 84.15 days (range, 6-605). The mean time from surgery to postoperative MRI was 16.11 months (range, 12-24.48). The mean AP size and retraction of all of the tears was 2.9 cm (range, 2.5-5.1 cm) and 2.1 cm (range, 0.5-4.47 cm), respectively. Thirty-three (83%) of the 40 patients exhibited intact repair sites based on postoperative MRI scans (Figures 3 *A*, *B*). There were 5 tears that were equal to or larger than 3.5 cm that had healed postoperatively.

Preoperative mean Goutallier classification for intact subjects was 0.27 (SD, ±0.57) compared to 1.3 (SD, ±1.15) for not intact subjects ($P = .01$). Overall, 7 of the 40 patients exhibited a progression in atrophy: 2 in the intact group and 5 in the not intact group. Both intact subjects demonstrated a progression from grade 0 to grade 1 while not intact subjects had variable results. Two subjects remained static at grade 2, 1 subject went from grade 0 to grade 1, and the final 2 subjects demonstrated substantial progression from grade 0 to grade 3. Figures 4, *A*, *B* show MRI images of a failed repair and the extensive fatty infiltration typical of the failed repairs. Image 5 shows an intact suture bridge with failed tendon around it, representative of the three revision cases performed in this series.

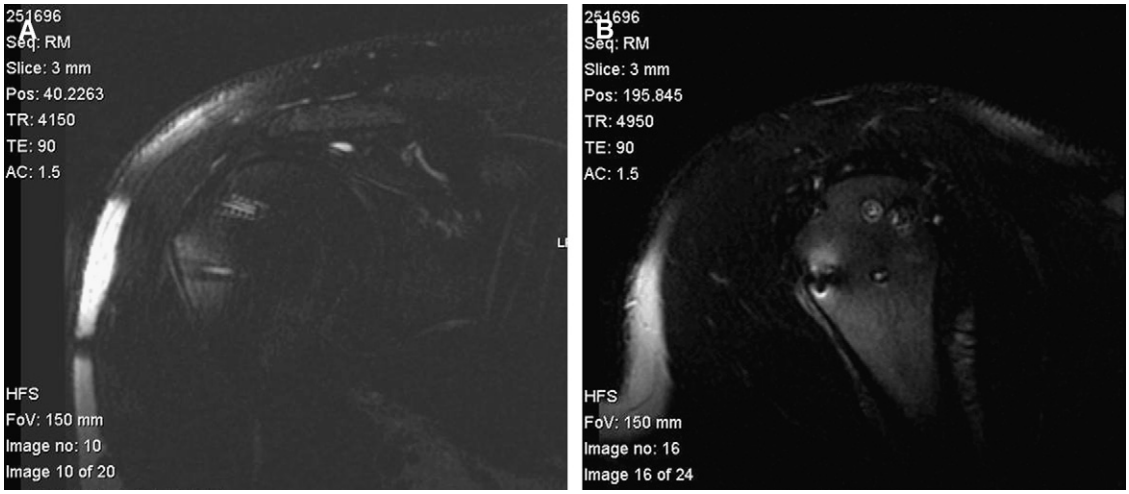

Figure 3 (**A**) Postoperative intact cuff, coronal T2 MRI. (**B**) Postoperative intact cuff, sagittal T2 MRI.

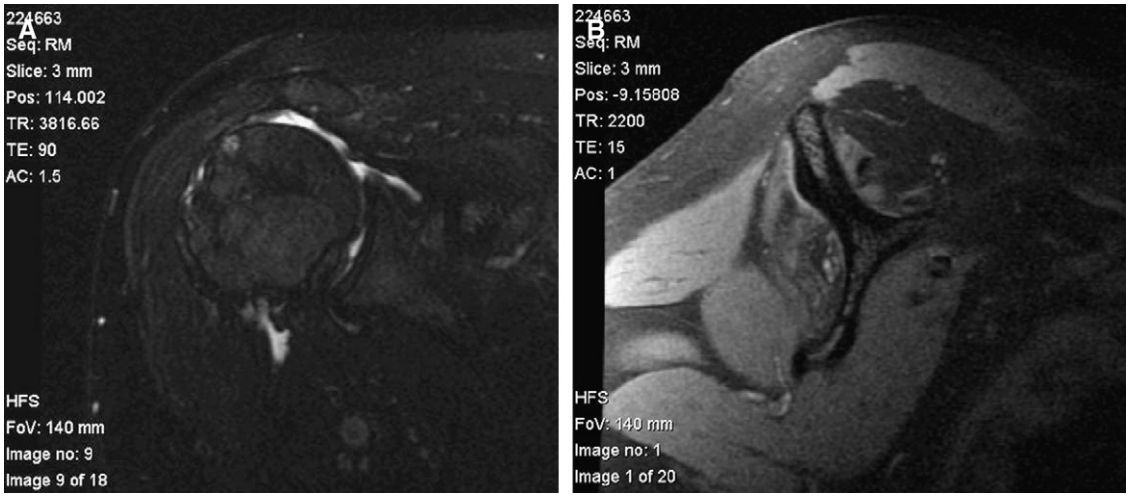

Figure 4 (**A**) Postoperative failed repair coronal T2 MRI showing RTC adhered to undersurface of acromion which was verified during revision surgery. (**B**) Same patient proton density MRI showing extensive Goutallier changes.

Surgical data

The mean number of medial and lateral anchors used was 2.25 and 2.1, respectively (no difference in number of anchors between groups). 5.5 Bio-corkscrew anchors (Arthrex) were used in all medial row repairs; while 3.5 PEEK Pushlock anchors (Arthrex) were used for all lateral row anchors. All suture anchors were double loaded. Twelve patients required side-to-side sutures based on tear morphology, to allow for an anatomic reduction (no difference in number of side to side repairs between groups). Associated procedures are shown in Table I. The preoperative mean size of tears for intact repairs was 2.8 (SD, $\pm$0.7) cm compared to 3.5 (SD, $\pm$0.6) cm for not intact ($P = .01$), and is shown in Table II.

Clinical outcomes

Among the failed repairs, 5 cases involved the right shoulder, 2 involved the left, 4 were males, and 3 were females, and all had an acromioplasty performed. In the failure group, 2 patients had labral debridement, 2 others needed a biceps tenodesis, and 1 patient had a subscapularis repair. Two patients had MRI documented tears 2 years prior to presentation and initially had isolated supraspinatus tears treated nonsurgically that then progressed to symptomatic larger tears. One patient was a revision procedure that had previous rotator cuff surgery 357 days prior. One patient was doing well and then had an acute fall at 8 months post surgery. Another patient had partial healing of the infraspinatus and the posterior aspect of the

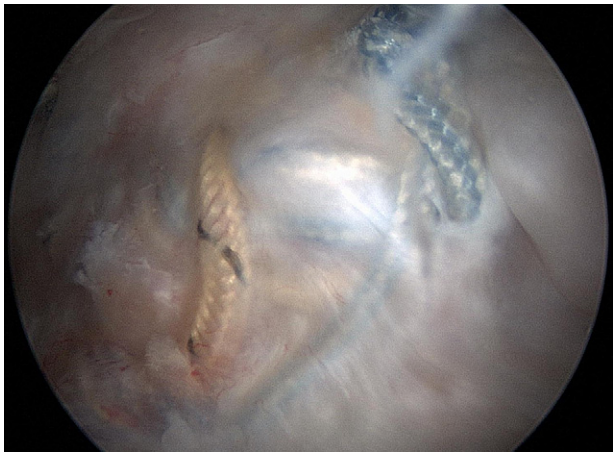

Figure 5 Tendon failure around intact suture bridge which was typical of the 3 revised cases.

supraspinatus, with a recurrent but smaller anterior defect and excellent clinical outcome. The final patient had advanced atrophy and tissue retraction beyond the AC joint. Four of the 7 patients who did not heal were clinically satisfied; the other 3 had subsequent surgery. None of the patients with intact repairs had secondary procedures.

Clinical outcomes were measured using the ROWE shoulder test, ASES subjective outcome measure, and the SST, and are shown in Table III. All patients had complete ROWE, ASES, and SST scores. There were no statistically significant differences between the groups on any of the clinical scoring systems. ASES scores were also evaluated on each subset (Table IV). The only significant difference was reduced strength in the not intact (6.86 ± 3.02) versus intact (9.2 ± 1.63) groups ($P = .01$). Post hoc power on the ASES was computed to be 0.37 based on the observed effect size. This low power may have been due to the relatively few numbers of tendons which failed to heal. Power was calculated post study, as the goal of this study was not to compare outcomes of intact versus non healed rotator cuff repair, rather to report on the healing rate after a certain type of repair.

There was a statistically significant difference in the abduction and forward flexion for postoperative shoulders when compared with the contralateral shoulder, although these values are not clinically relevant (Table V).

Discussion

Surgical technique and suture configurations have further advanced rotator cuff repair to recapitulate anatomy, contact area, and apply pressure across surgical constructs. Despite these improvements, the clinical significance of all these advancements with respect to rotator cuff healing remains still unclear.[5,6,19]

This study demonstrated an 83% healing rate after arthroscopic repair of 2-tendon tears as determined by postoperative MRI. The variable reported rates of rotator cuff healing reflect a heterogeneous sample of patients ages, tears sizes, and repair configurations and is challenging to interpret.[4,12] When 2-tendon tears are specifically isolated, the rate of tendon healing decreases. Nho et al recently published data showing an approximately 46% intact repair rate for 2-tendon tears evaluated by US at 2 years post-op, with larger tears and older patients healing less often.[18] Galatz et al reported retears in 17 out of 18 patients who underwent arthroscopic single row repair for large and massive (>2 cm in the transverse dimension) RTC tears when evaluated by US at a minimum of one year follow-up.[12] Bishop et al demonstrated that with single row repair, 84% of tears smaller than 3 cm were intact, while only 24% of tears larger than 3 cm were intact on 1-year follow-up MRI.[2] Sugaya et al demonstrated a retear rate of 5% for small to medium sized tears and 40% for large and massive sized tears.[23] Our data represent an in incremental improvement of the healing rate for two tendon tears with the TOE repair technique. Current studies demonstrate a higher healing rate for double row rotator cuff repair when compared to single row but fail to reveal a clinical advantage; these studies also represent a heterogeneous group of tear sizes and repair techniques. Franceschi et al reported no significant difference in healing rate or clinical outcomes in large to massive tears using single versus double row fixation (69.2% double row, 53.8% single row).[9] Charousset et al reported a 77% healing rate in double row versus a 60% healing rate ($P = .03$) in single row repair in medium sized tears with no differences in clinical outcomes.[6] Park et al followed 78 patients in a cohort study and found that patients with large to massive tears (>3cm), double row repair did show significantly better results than single row, leading those authors to recommend double-row repair in larger tears.[19] Burks et al performed either a single row simple repair or a double row using a simple configuration laterally and a diamond configuration medially on 40 patients with small to medium sized (mean 1.85 cm) full thickness RTC tears.[5] At 1-year follow-up, they found no differences in clinical outcomes (WORC, Constant, ASES, UCLA, SANE, and strength testing) or MRI findings.

Frank et al published the only series of TOE repairs,[10] and reported an overall 88% healing rate in a majority of supraspinatus tears. Similar to our results, the clinical assessment measures failed to show any difference between the failed or intact repairs, with the only significant difference being found in the UCLA scores.[10]

Our data on TOE repairs resulted in an 83% healing rate, suggesting that 2-tendon rotator cuff tears may be able to heal at a similar rate to the published reports of single-tendon tears. In our study, the patients who had recurrent tears had statistically larger tears than those who had healed, although no threshold for tear size precluding healing was identified. Recurrent tears were associated with tears greater than 3.5 cm, although 5 patients with tears greater than or equal to 3.5 cm healed post-surgically. Despite the absence of

Table III Postoperative clinical scores for intact and nonintact rotator cuff repairs

Measure	Intact mean (SD)	Nonintact mean (SD)	Mean difference	95% CI	*P* value*
ROWE	94.57 (±6.21)	83.0 (±17.44)	11.57 (±6.69)	−4.58-27.7	.13
ASES	93.30 (±11.24)	81.43 (±21.45)	11.87 (±8.36)	−8.03-31.8	.20
SST	11.30 (±1.37)	10.14 (±3.33)	1.16 (±1.29)	−1.94-4.3	.40

* Value for the difference.

Table IV Components of the American Shoulder and Elbow Surgeons (ASES) Rating Scale for intact vs nonintact repairs

Measure	Intact mean (SD)	Nonintact mean (SD)	Mean difference	95% CI	*P* value
Pain Rating	0.73 (±1.24)	1.86 (±2.12)	−1.12 (±0.83)	−3.09-0.84	.22
Shoulder Function	27.97 (±4.55)	24.57 (±6.78)	3.395 (±2.69)	−2.92-9.71	.25
Strength	9.20 (±1.63)	6.86 (±3.02)	2.343 (±1.18)	0.69-3.99	.01†
Stability	24.83 (±0.91)	25.0 (±0)	−0.17 (±0.17)	−0.51-0.17	.33

Pain: 0 = no pain at all; 10 = distinct and marked pain. Shoulder function: 0 = no usable function whatsoever; 30 = able to participate in everyday tasks without difficulty. Strength: 0 = little or no strength; 10 = normal strength. Stability: 25 = full stability, 0 = no stability.
† Significant value ($p < .05$).

controls, such as single row or standard double row repair, this represents a reportable finding.

Although age greater 65 years old has been correlated with lower rate of tendon healing,[4,18] age was not significantly different between the intact and not intact groups in this study. Goutallier grading was statistically different between intact and unhealed tendons, consistent with other reports.[14]

We did not show a statistical significance between healed and unhealed patients with respect to outcomes scores (ASES, ROWE, and SST). Only the strength component of the ASES was significantly different ($P = .01$), which has been shown in other reports as well.[1,23] This could be a consequence of insufficient power for this study and a disproportionate rate of healing in the study group. Postoperative intact rotator cuffs had a mean ASES score of 94.57 as compared to 83 for unhealed subjects, which mirrors the scores demonstrated in Nho et al.[18] Despite the lack of a difference in the validated scoring systems, all 33 (100%) patients with intact repairs were satisfied post surgery and required no secondary procedures. In contrast, 3 of the 7 (43%) unhealed patients were unsatisfied and underwent revision procedures. Physical examination of the unhealed patients revealed obvious differences in strength in scaption. Although these descriptions do not translate into difference in the normative scores, they do indeed represent a difference in patient outcome. Perhaps a larger series of patients would yield a statistical difference, but the cost of a larger study was prohibitive. It is also possible that the outcome measures used in this study (ASES in particular) may not be sensitive or accurate enough to quantify the differences that are apparent between the 2 groups.

We used 3.5-mm press fit (Pushlock; Arthrex) anchors during this study period. Since that time, we progressively moved to larger press fit anchors and currently use a bio-composite screw in anchor, because of progressively increased pullout strength with the later anchors. It appears that that lateral anchor pullout strength may not be as important, as there were zero failures as a result of pullout of these anchors.

This study has unique strengths. We studied 40 consecutive patients with a single, consistent surgical technique which was completed in a private practice. None of the authors have any requirement or reward for publication nor do any have a financial interest in the implants used. None of the authors were involved in the development of this technique. We report a high healing rate for 2-tendon tears of the rotator cuff that represents an incremental improvement that we attribute to a certain surgical technique.

Limitations associated with this study include the fact that normative preoperative data are not presented for the patients and the absence of a control group. In fact, this data were not routinely collected during the first half of this study. Patients enrolled later in the study did have data collected, which when examined was consistent with historical controls and the subsequent improvement post surgery. While this information would be useful, it does not impact the integrity of cuff healing as judged by postoperative MRI scan. Ideally, we would have compared a single row, double row and a TOE equivalent. The durability of this repair will need to be studied and these patients have all been enrolled in a study designed for 10-year follow-up with MRI evaluation.

Not all rotator cuff repairs will heal; this may represent the limitations of biological healing in certain situations. Despite the limitations of healing, the biomechanics of repair continue to improve. This study provides support that the biomechanical advantages of TOE repairs can result in a higher rate of healing than previously reported for tears of

Table V Postoperative range of motion for all rotator cuff repairs

	Operated shoulder (°) mean (SD)	Contralateral shoulder (°) mean (SD)	*P* value*
External rotation	72.8 (±14.7)	74 (±13.7)	.38
Abduction	144.3 (±31.3)	148.1 (±31.9)	.049†
Forward flexion	172.1 (±8.7)	173.9 (±6.8)	.047†

* Value for the difference.
† Significant value ($P < .05$).

similar size; but the clinical advantages of this are still unclear.

Conclusions

This study shows that 2-tendon rotator cuff tears (greater than 2.5 cm in AP diameter) healed in 83% of cases when repaired with a spanning transosseous equivalent repair. This study lends clinical support to the previously defined biomechanical advantages of TOE technique for repair of the rotator cuff.[3,10,22] Furthermore, tear size and Goutallier grading were negatively correlated with postoperative healing. The incremental improvement in the rate of observed rotator cuff healing still does not translate to statistical differences in the objective shoulder scoring systems.

Disclosure

Dr. Sethi has received royalties and performed consultation work with Arthex Inc. Dr. Sethi, his immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article. All other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Institutional Review Board approval was given by the Greenwich Hospital, CT # 2007006 and all patients gave informed consent to participate.

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