

Successful Revision Arthroscopic Rotator Cuff Repair Is Possible in the Setting of Prior Deep Infection



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Purpose: To report on clinical outcomes of revision arthroscopic rotator cuff (RC) repair in the setting of prior deep infection. **Methods:** A retrospective review was conducted of a single surgeon's experience treating patients with deep infection after RC repair. Pain by visual analog scale (VAS), American Shoulder Elbow Society (ASES), Simple Shoulder Test (SST), and Single Assessment Numeric Evaluation (SANE) scores, as well as active range of motion, were collected preoperatively and at final follow-up. **Results:** Three patients age 54.0 ± 7.5 years, mean \pm standard error of the mean) with mean follow-up of 62 months (range 24 to 83) were treated for deep infection after RC repair. Improvements were observed in all subjective and objective outcomes; VAS pain (5.0 ± 0.6 vs 0.3 ± 0.3 , $P = .005$), ASES score (37.2 ± 4.0 vs 93.9 ± 6.1 , $P = .003$), and active forward elevation ($68.3^\circ \pm 28.5^\circ$ vs $173.3^\circ \pm 6.7^\circ$, $P = .06$.) Excellent outcomes in SST (mean 11.3 ± 0.7) and SANE (95.0 ± 5.0) scores were also observed. No recurrent infections were noted at final follow-up. **Conclusion:** Arthroscopic reconstruction of the RC is a feasible goal in the setting of prior deep infection. When a thorough arthroscopic debridement can be achieved, it is possible to address residual RC tears with either revision repair or allograft reconstruction with the possibility of excellent short-term clinical outcomes. **Level of Evidence:** Level IV, retrospective case series

Deep infection after arthroscopic¹⁻³ or open^{4,5} rotator cuff (RC) repair is very uncommon, with multiple reports suggesting rates of infection occurring between 0.16% and 0.85% of cases. Accordingly, published treatment recommendations for infected RC repairs have been based on case series and expert opinions, which have detailed a variety of surgical tactics ranging from serial debridement with and without revision open RC repair to radical soft tissue excision requiring myocutaneous flap coverage.⁶⁻⁸ The existing literature pertaining to infected RC repairs is limited and suggests that a staged

approach with ≥ 2 surgical debridement procedures may be necessary to eradicate deep infections.^{9,10}

When confronted with a deep infection after RC repair, the surgeon often must decide how to address retained orthopaedic implants, namely biocomposite or nonabsorbable sutures and suture anchors. Similarly, the surgeon must decide whether a single-stage debridement is likely to eradicate a deep infection and, ultimately, whether an attempt at revision repair is advisable. Although a recent case series comprising 11 patients showed that infection may be successfully eradicated with arthroscopic debridement and implant retention, we are unaware of any literature that indicates whether revision arthroscopic RC repair can be successful in the setting of a previous deep infection.¹¹ The purpose of this case series is to report on clinical outcomes of revision arthroscopic RC repair in the setting of prior deep infection. We hypothesized that arthroscopic rotator cuff reconstruction after debridement with retention of well-fixed implants and antibiotics would result in improved pain and functional outcome scores for patients with deep infection after primary RC repair.

Methods

A review of the surgical records of the senior author (S.S.B.) over a 10-year period was performed to identify cases of revision arthroscopic RC repair performed

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Table 1. Patient demographic information

	Age (y)	Sex	Affected Shoulder	Dominant Arm	Diabetes Mellitus	Smoking Status
Patient 1	41	M	Right	Right	Negative	No
Patient 2	54	M	Right	Right	Positive	No
Patient 3	67	M	Left	Left	Negative	No

in the setting of a prior deep infection and treated in conjunction with an Infectious Disease specialist. Superficial wound complications treated as portal infections with oral antibiotics were excluded. Outside records, operative notes, and all documentation pertaining to prior treatments were reviewed, including those from our Infectious Disease colleagues. Pain by visual analog scale (VAS), American Shoulder Elbow Society (ASES) score, and active shoulder ranges of motion were collected preoperatively and at final follow-up. Simple Shoulder Test (SST) and Single Assessment Numeric Evaluation (SANE) scores were assessed at final follow-up.

For statistical analysis, descriptive statistics were used for continuous data. Paired *t* tests were used to compare means. Statistical significance was set at $P < .05$.

Results

Three cases of infected RC repair were identified, with a mean follow-up of 62 months (range 47 to 83). The mean (\pm standard error of the mean) age of patients in this series was 54.0 ± 7.5 years (range 41 to 67) (Table 1). All 3 patients were men. Pre- and postoperative functional outcome scores for the patients are included in Table 2. VAS pain improved from preoperative 5.0 ± 0.6 (range 3.9 to 6.1) to postoperative 0.3 ± 0.3 (range -0.3 to 1.0), $P = .005$. Significant improvements were observed between ASES scores at the time of presentation and at final follow-up (37.2 ± 4.0 vs 93.9 ± 6.1 , $P = .003$). Excellent outcomes were observed with respect to mean SST and SANE scores (11.3 and 95, respectively). Mean active forward elevation of $68.3^\circ \pm 28.5^\circ$ and external rotation of $30.0^\circ \pm 0.0^\circ$ improved to $173.3^\circ \pm 6.7^\circ$ ($P = .06$) and $53.3^\circ \pm 12.0^\circ$ ($P = .2$), respectively.

Case 1

A 41-year-old right-hand-dominant man with no significant medical history sustained a traumatic massive RC tear of the subscapularis, supraspinatus, and infraspinatus of the right shoulder in a dirt bike crash. He also sustained an ipsilateral type

3 acromioclavicular (AC) joint separation and cervical spine fracture, both of which were treated non-operatively. He was hospitalized overnight for observation after the injury, and 3 weeks later, he underwent open rotator cuff repair by his referring surgeon. Double-row repair of the rotator cuff was performed using a combination of metal and bio-absorbable suture anchors, 5 medially and 3 laterally. A biceps tenodesis was performed using a single interference screw. The operative time was noted to be 4 hours.

The patient developed wound drainage ~ 12 days after the index procedure. Reoperation occurred on postoperative day 15, and evidence of deep infection was found, with gross purulence and loss of RC repair fixation. The nonabsorbable sutures and tenodesis screw were removed, but all remaining anchors were left in place. Operative cultures returned positive but were reported only as "skin flora." Postoperatively, the patient was treated with intravenous (IV) vancomycin for 6 weeks.

The patient was referred to our clinic 3 months after completion of antibiotic therapy. No evidence of clinical infection existed, and inflammatory laboratory values [erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), leukocyte count] were found to be within normal limits. On clinical examination, the patient had pseudoparalysis of the right shoulder, with active forward elevation of 30° , but with preserved, full passive elevation. Plain radiographs of the affected shoulder showed retained hardware within the greater tuberosity, no evidence of bone loss or significant glenohumeral arthrosis, and a preserved joint space. Magnetic resonance imaging (MRI) of the affected shoulder revealed a massive rotator cuff tear without evidence of underlying osteomyelitis (Figure 1).

At the time of arthroscopic treatment, a massive, contracted rotator cuff tear measuring 5×9 cm, involving 100% of the supraspinatus, infraspinatus, and subscapularis tendons, was noted. Neither the bone nor soft tissues exhibited any evidence of ongoing

Table 2. Pre- and postoperative functional outcome scores

	VAS		SST	ASES		SANE
	Preoperative	Postoperative	Postoperative	Preoperative	Postoperative	Postoperative
Patient 1	4	1	12	45	100	100
Patient 2	6	0	10	35	81.6	85
Patient 3	5	0	12	31.6	100	100

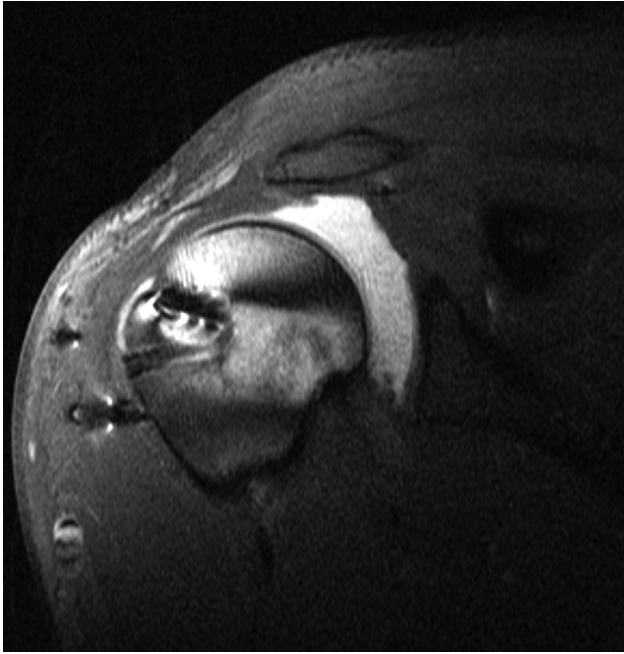


Figure 1. Right shoulder coronal magnetic resonance image shows a retracted supraspinatus tear with retained anchors.

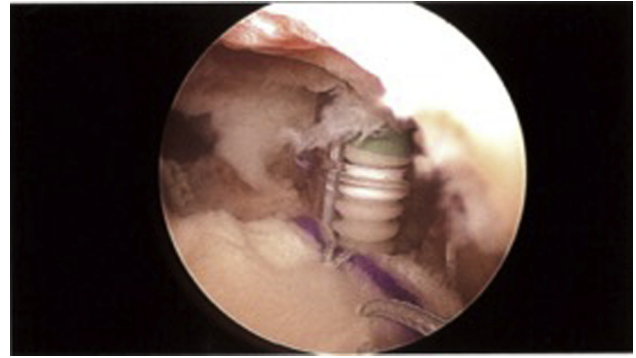


Figure 2. Right shoulder arthroscopic viewing from a posterior portal shows humeral fixation of a bridging dermal allograft.

infection. A complete, single-row repair of the subscapularis tendon was achieved after 3-sided mobilization, anterior interval slide in continuity, and medialization of the bone bed.^{12,13} After mobilizing the remaining posterosuperior RC, it was clear that the supra- and infraspinatus tendons were irreparable. A 35 × 30-mm dermal allograft (Arthroflex; Arthrex, Naples, FL) was used to bridge the defect between the remaining RC and the tuberosity. The graft was fixed to the medial and posterior cuff margins with simple 2-0 Fiberwire (Arthrex) sutures and to the greater tuberosity using three 4.75-mm SwiveLock-C (Arthrex) anchors (Figure 2).

Postoperatively, at the discretion of the Infectious Disease consultants, the patient was maintained on IV vancomycin and ceftriaxone for 3 weeks pending operative cultures. Final operative cultures (aerobic, anaerobic, fungal, acid fast bacilli, and mycobacteria) from the revision RC repair showed no evidence of organism growth. The patient was instructed to use an abduction sling for 6 weeks postoperatively with no shoulder range of motion and only active range of motion of the elbow, wrist, and hand. Six weeks after surgery, home physical therapy with passive shoulder range of motion only was initiated. Three months after surgery, active shoulder range of motion and strengthening were started under the direction of a physical therapist.

At final follow-up (56 months), the patient had an excellent outcome (Table 3.) His active forward elevation was 180°, with reversal of his pseudoparalysis. His type 3 AC joint separation remained asymptomatic.

Case 2

A 54-year-old right-hand-dominant man with type 2 diabetes mellitus injured his right shoulder lifting a suitcase and failed nonoperative treatment with 2 subacromial corticosteroid injections and physical therapy. The patient underwent right shoulder open rotator cuff repair by his referring surgeon. The tear pattern was identified as massive reverse-L, involving 100% of the supra- and infraspinatus tendons. A linked, double-row repair was performed using 4 bio-composite suture anchors.

One month after surgery, the patient developed fever and swelling about the shoulder. Two weeks later, drainage from the surgical wounds was noted. The wound was opened in the office and allowed to drain, and the patient was placed on oral doxycycline. His clinical status subsequently deteriorated, and he was referred to our clinic. We evaluated the patient 6 months postoperatively. He was not satisfied with his shoulder, reporting severe pain and poor function. On examination, his incision had healed by secondary intention. He had pseudoparalysis, with active forward elevation of 45° and preserved, full passive elevation. Laboratory values showed a normal leukocyte count and ESR, but the CRP was elevated at 12.6 mg/dL (normal range 0 to 7 mg/dL).

At the time of the first revision arthroscopic surgery, a massive, 5 × 6-cm tear involving the upper 50% of the subscapularis tendon, 100% of the supraspinatus, and 50% of the infraspinatus was noted. Intraoperative Gram stain was performed, showing the presence of Gram-positive cocci. The supra- and infraspinatus tendon tissue appeared friable and nonviable and were presumed to be infected. Additionally, all 4 suture anchors were loose, and cystic changes in the bone of the greater tuberosity were noted. Adequate debridement of the soft tissues and bone was achieved arthroscopically. The subscapularis tendon and bone bed appeared well and without any evidence of prior subscapularis repair (Figure 4A). Therefore, primary repair of the

Table 3. Range of motion assessment of affected shoulder

	Active Forward Elevation (°)		Internal Rotation (Spinal Level)		External Rotation (°)	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Patient 1	35	160	L5	L1	30	30
Patient 2	45	180	L2	T7	30	60
Patient 3	125	180	L2	L1	30	70

upper subscapularis was performed using Fibertape (Arthrex) and a 4.75-mm SwiveLock-C suture anchor^{14,15} (Figure 4B). The large bone defects in the greater tuberosity were then grafted with cancellous bone chips using the Osteochondral Autograft Transfer System (OATS) recipient cutting tube (Arthrex).¹⁶

Operative cultures were retained for 3 weeks but ultimately did not show any organism growth. The patient was kept on IV levofloxacin for 3 weeks postoperatively and then was transitioned to oral linezolid for an additional 3 months, at the recommendation of the Infectious Disease consultant. The postoperative rehabilitation protocol again consisted of 6 weeks in a sling with no shoulder range of motion, then 6 weeks of passive shoulder motion only, and finally initiation of active shoulder range of motion and strengthening 3 months postoperatively. One year after surgery, the patient no longer showed pseudoparalysis, with active forward elevation of 160°. However, he did continue to complain of persistent weakness. MRI of the affected shoulder showed consolidation of the bone graft and healing of the subscapularis repair, but a residual defect of the posterosuperior cuff with approximately 50% fatty infiltration of the supra- and infraspinatus muscles (Figure 3). Inflammatory indices (ESR, CRP, leukocyte count) were found to be within normal limits.

In light of the patient's persistent weakness and shoulder dysfunction, revision arthroscopic RC repair was performed. At the second arthroscopic revision, a 5 × 5-cm tear of the supra- and infraspinatus tendons was found. Concordant with the MRI of the shoulder obtained before revision arthroscopic RC repair, the subscapularis tendon was completely healed (Figure 4C), and the greater tuberosity bone graft had consolidated. A thorough arthroscopic inspection of the glenohumeral joint and subacromial space did not reveal any evidence of an ongoing infection. The RC tear was inspected and classified as a reverse-L tear, which was repaired with margin-to-bone construct at the tear apex and load sharing rip stop (LSRS) construct for the supraspinatus and infraspinatus^{17,18} (Figure 4D). Three biocomposite Corkscrew FT (Arthrex) suture anchors were used at the medial row, and two 4.75-mm SwiveLock-C suture anchors secured the Fibertape sutures from the rip stop. Platelet-rich plasma (Autologous Conditioned Plasma; Arthrex) was injected at the tendon–bone interface under direction visualization at the conclusion of the surgery.

Operative cultures from the final revision showed no organism growth 3 weeks after surgery. During this time, the patient was maintained on a dual regimen of oral antibiotics (cephalexin and doxycycline) for 2 weeks. The second postoperative rehabilitation program was identical to that used after his first revision. At final follow-up (83 months), the patient had an excellent outcome, with maintenance of active overhead use of the arm (Table 3.)

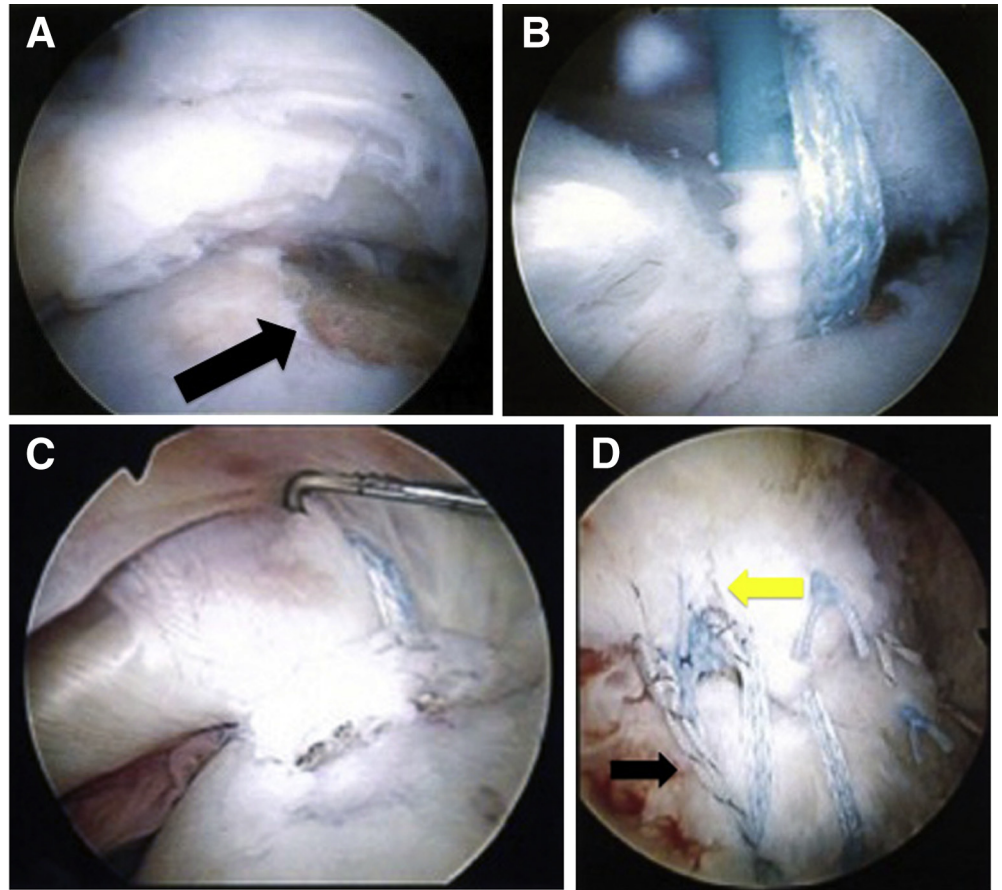
Case 3

A 67-year-old left-hand-dominant man underwent arthroscopic repair of a massive rotator cuff tear involving both the supraspinatus and infraspinatus of the left shoulder using bioabsorbable suture anchors (2 medial row, triple loaded; 1 lateral row). One week after surgery, he developed increasing pain and swelling. The shoulder was aspirated twice over the course of 7 days in the office of the referring surgeon. Aspirates grew coagulase-negative Staphylococci (*S. warneri*). Three weeks after surgery, the patient underwent arthroscopic debridement with suture removal. Suture anchors were left in place, and the



Figure 3. Right shoulder coronal magnetic resonance image shows a retracted supraspinatus tear and bare lesser tuberosity (black arrow) after debridement of deep infection.

Figure 4. Right shoulder 70° arthroscopic view of an upper subscapularis tendon tear from inside the glenohumeral joint (A), knotless repair of the tear at the time of initial arthroscopic debridement (B), and the healed subscapularis repair at the time of final rotator cuff reconstruction (C). (D) Right shoulder 30° lateral view showing a load-sharing rip stop repair of the posterosuperior rotator cuff. The Fiberwire stitches (yellow arrow) have been passed and tied medial to the Fibertape sutures (black arrow), which are passed in a mattress fashion and fixed to a knotless anchor laterally.



repair was noted to be completely disrupted. The patient was placed on IV vancomycin and referred to our clinic.

The patient was evaluated ~4 weeks after surgery. Per the recommendations of the Infectious Diseases consultant, he was treated with IV vancomycin for a total of 6 weeks, and a course of nonoperative treatment was pursued. The patient was reevaluated ~6 months after the index arthroscopic RC repair. He was not satisfied with his pain relief or function (Table 3). He had no clinical signs of infection, and his inflammatory indices (ESR, CRP, leukocyte count) were found to be within normal limits. An MRI of the affected shoulder showed a massive, posterosuperior rotator cuff tear without evidence of underlying osteomyelitis (Figure 5).

At the time of revision arthroscopic surgery, a 4 × 5-cm tear was found encompassing 100% of the supraspinatus and 50% of the infraspinatus (Figure 6A). A double interval slide was performed to obtain adequate tendon mobilization.¹⁹ A double-row repair construct of the infraspinatus was achieved using 2 medial Biocomposite Corkscrew FT suture anchors and 2 lateral SwiveLock-C anchors, and a LSRS was used additionally to repair the supraspinatus^{17,18}

(Figure 6B). Platelet-rich plasma was injected under direct visualization at the tendon–bone interface at the conclusion of the surgery.

Operative cultures from the final revision showed no growth 3 weeks after surgery. The patient was treated with 2 months of oral doxycycline at the recommendation of the Infectious Disease consultant. Again, passive shoulder range of motion was deferred until 6 weeks postoperatively, and active shoulder range of motion and strengthening was restricted until 3 months postoperatively. At final follow-up (47 months), the patient was found to have markedly improved shoulder function (Table 3.)

Discussion

The results of the study support the hypothesis that the rotator cuff–deficient shoulder with prior deep infection can be treated successfully, as shown by improvement in pain and function at short-term follow-up, using a strategy that prioritizes RC reconstruction after adequate treatment of the infection. Because deep infection after RC repair is very uncommon, minimal information is available about the results of RC reconstruction in this setting.²⁰ The current series provides evidence that well-fixed biocomposite and



Figure 5. Left shoulder coronal magnetic resonance image shows retracted supraspinatus tear (yellow arrow) without evidence of osteomyelitis.

nonabsorbable stable suture anchors may be retained in the face of deep infection. Moreover, these results suggest that infection may successfully be eradicated through either a single- or limited-stage arthroscopic approach, with debridement performed in conjunction with revision RC repair. These excellent clinical outcomes show that revision arthroscopic RC repair should be considered in cuff-deficient shoulders previously treated with for deep infection.

A more aggressive approach toward eradication of infection has previously been described in several reports,^{7,8} which have detailed radical open procedures, routine removal of all foreign material or routine

staging of debridement, and possibly revision repair and/or bone grafting. Although it would be reasonable to consider this type of aggressive approach on a case-by-case basis, routinely removing all implants as part of a multistage surgical approach risks unnecessary reoperations and bone and soft tissue destruction after multiple debridements that may preclude the possibility of future RC reconstruction. Of course, successful implant retention likely depends on the adequacy of surgical debridement and antibiotic treatment. If loose anchors are found intraoperatively, these should be removed, as was done in case 2. The necessity of implant removal invariably compromises the remaining greater tuberosity bone stock, which is likely to increase the complexity of any subsequent revision procedure. Humeral bone loss can be treated by using the OATS recipient cutting tube to perform impaction bone grafting before the insertion of new suture anchors during a second-stage procedure.

The preponderance of the existing literature pertaining to the surgical management of infected RC repairs suggests that a multistage approach, usually performed using open techniques, should be undertaken to adequately treat the underlying infection. Settecerrri et al.¹⁰ reported on a series of 16 patients treated for infection after RC repair, noting that a mean of 3.5 procedures (range 2 to 8) were required to eradicate the infection. In fact, those authors specified that the surgical wounds were left open and packed with povidone-iodine-soaked gauze between debridements. Similarly, in a comparably sized series, Kwon et al.⁸ observed a mean of 2.6 procedures (range 1 to 6) performed to fully treat the underlying infection. In the largest series of infected RC tears to date, Athwal et al.²¹ reported that all of their 39 cases were treated with ≥ 1 open debridement. Conversely, in our series, all patients' infections were successfully treated arthroscopically without the need for multiple, open debridements.

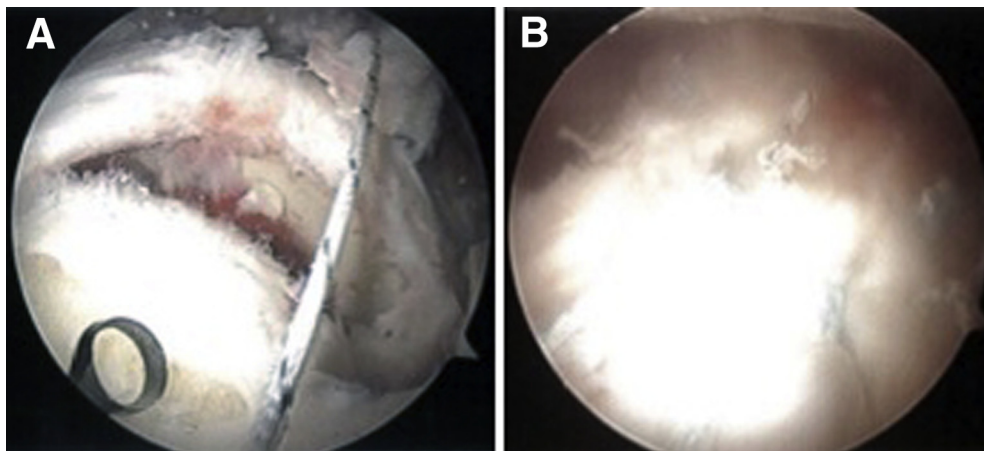


Figure 6. (A) Left shoulder 70° view from a posterior portal showing a massive, contracted rotator cuff tear. (B) A complete repair was obtained after performing double interval slides.

In the past 3 decades, our knowledge of biofilms as a mechanism of organism treatment resistance has expanded markedly. Although a great deal is known about the necessity for implant extraction in the setting of chronically infected total hip and knee arthroplasty, there is a relative paucity of information on the role that biofilms may play in the setting of retained suture anchors and infected RC repairs. Thus, the advantages and disadvantages of implant removal and staging in the setting of infected rotator cuff repair should be examined critically, on a case-by-case basis. We would discourage surgeons from reflexively adopting aggressive approaches to treatment of rotator cuff deep infection that might affect the surgeon's ability to attempt revision RC repair or subject the patient to numerous reoperations. The unnecessary removal of well-fixed implants jeopardizes the available greater tuberosity bone stock.

In our view, an arthroscopic procedure provides the surgeon with enhanced visualization of all intra- and extra-articular pathology, which theoretically allows for an optimal debridement and a thorough inspection of the implants from the index procedure. Each retained implant should be scrutinized for loosening. Loose nonabsorbable suture should be completely removed. Suture anchors should be tested for stability and examined for evidence of infection. Stable, benign-appearing anchors can be left in place to preserve tissue for re-repair or reconstruction, which, as shown in this report, can be successfully performed in either a single- or limited multistage approach.

The current study stands in contrast with those reported previously, where infection eradication has often been achieved at the expense of poor residual shoulder function.^{8,10,21} Perhaps what has been reported previously represents an overly aggressive approach to debridement. The mean number of debridements reported in the literature ranges from 2.4 to 3.5, with open debridement performed almost universally.^{8,10,21} Additionally, a review of the available literature reveals that it was not uncommon for residual RC tears to go unrepaired in the setting of infections treated with multiple debridements. Although Jenssen et al.¹¹ recently reported on the short-term outcomes of arthroscopic debridement of infected RC repairs, 8 of the 10 patients in that series presented with intact RC repairs, and no revision RC repair was attempted in the remaining 2 patients.

It should be noted that in 1 of our 3 cases, revision surgery was undertaken not for repeat debridement, but for repair of a massive, L-shaped RC tear previously not amenable to a 1-stage repair given the amount of greater tuberosity bone loss encountered after initial implant removal. With good mechanical fixation and conservative rehabilitation protocols, our opinion is that RC reconstruction can be achieved even in the

difficult setting of treated deep infection, leading to marked improvements in patients' pain and shoulder function.

Limitations

The limitations of this report are obvious, as this small case series represents the experience of a single surgeon. The small number of patients limits meaningful statistical comparisons, although this is not unexpected given the low incidence of infection after RC repair. Moreover, the fact that a single surgeon performed all procedures introduces the possibility of performance bias and may limit the external validity of this report's findings.

Conclusions

Arthroscopic reconstruction of the RC is a feasible goal in the setting of prior deep infection. When a thorough arthroscopic debridement can be achieved, it is possible to address residual RC tears with either revision repair or allograft reconstruction with the possibility of excellent short-term clinical outcomes.

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