Original Article

Partial Rotator Cuff Repair Provides Improved Patient-Reported Outcome Measures Following Superior Capsule Reconstruction (SCR)

Jarret M. Woodmass, M.D., F.R.C.S.C., Eric R. Wagner, M.D., M.S., Kathryn M. Welp, M.S., Michelle J. Chang, B.S., Marc P. Morissette, M.S., Ph.D., C.A.T.(C), Laurence D. Higgins, M.D., M.B.A., and Jon J. P. Warner, M.D.

Purpose: To evaluate the role of concomitant partial rotator cuff repair (RCR) (i.e., infraspinatus) on patient-reported clinical outcomes following superior capsule reconstruction (SCR). **Methods:** Postoperative recovery outcomes of SCR alone were compared with SCR with concomitant infraspinatus rotator cuff repair (SCR+RCR) at 3, 6, 12, and 24 months. Patients were included if they had an SCR surgery with or without a concomitant infraspinatus repair. Patients were excluded if they did not have a minimum of 6 months' follow-up or if a preoperative baseline questionnaire was not performed. Outcome measures included pain visual analog scale, American Shoulder and Elbow Surgeons (ASES) Shoulder Function, ASES Shoulder Index, and Single Assessment Numeric Evaluation (SANE) score. **Results:** Overall, 180 patients were evaluated, including 163 patients who underwent SCR alone and 17 patients who underwent concomitant infraspinatus repair (SCR+RCR). There was no difference in demographic data including age, sex, and body mass index. The postoperative recovery curves demonstrated SCR alone and SCR+RCR both provide significantly improved pain and functional scores at 2 years postoperatively ($P < .001$). When we compared the 2 groups, SCR+RCR provided significantly improved ASES Index (87.6 vs 78.2, $P = .048$) and ASES Function (25.5 vs 21.7, $P = .02$). There was no statistically significant difference in SANE scores (75.5 vs 64.2, $P = .07$) at 24 months' follow-up. **Conclusions:** SCR provides modest improvements in pain and function at 2 years postoperatively in patients with irreparable rotator cuff tears. Patients who underwent SCR and concomitant infraspinatus repair demonstrated significantly improved ASES Index and ASES Function scores and statistically nonsignificant improvement in SANE scores at 24 months postoperatively when compared with SCR alone. **Level of Evidence:** III, retrospective cohort study.

From the Pan Am Clinic, University of Manitoba, Winnipeg, Manitoba, Canada (J.M.W., M.P.M.); Department of Orthopedic Surgery, Emory University, Atlanta, Georgia, U.S.A. (E.R.W.) Tufts University School of Medicine, Boston, Massachusetts, U.S.A. (K.M.W.); Kansas City University of Medicine and Biosciences, Kansas City, Missouri, U.S.A. (M.J.C.); King Edward Memorial Hospital, Hamilton, Bermuda (L.D.H.); and Department of Orthopedic Surgery, Massachusetts General Hospital, Boston, Massachusetts, U.S.A. (J.J.P.W.).

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Address correspondence to Jarret Woodmass, M.D., F.R.C.S.C., Pan Am Clinic, University of Manitoba, 75 Poseidon Bay, Winnipeg, Manitoba, Canada R3M 3E4. E-mail: jwoodmass@panamclinic.com

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Irreparable rotator cuff tears represent a treatment challenge for shoulder surgeons. Chronic tears with high-grade fatty infiltration,[1-3] short tendon length,[3,4] and a high degree of retraction[2,3] demonstrate high rates of clinical failure or retear.[5] In those patients who are nonresponsive to conservative management,[6] common surgical options can be categorized into palliative interventions (debridement, biceps tenotomy/tenodesis,[7] suprascapular nerve release[8]), attempted restoration of native force couples (partial rotator cuff repair,[9] bridging techniques[10]), or reconstruction (superior capsule reconstruction [SCR],[11-14] tendon transfers[15-21]).[22]

Partial rotator cuff repair (pRCR) is proposed to reestablish the rotator cable to provide a "suspension bridge" effect, thus restoring normal force–couple mechanics.[23] Although pRCR can improve pain and function,[24] deteriorating results in longer-term follow-up are noted, with up to 50% of patients not being satisfied at 2 years' postoperatively.[25] In an attempt to

Table 1. Response Compliance

	Preoperative	6 Months	1 Year	2 Years
VAS Pain Score				
SCR only	99% (161)	94% (153)	84% (137)	74% (121)
SCR+RCR	100% (17)	100% (17)	88% (15)	88% (15)
ASES Shoulder Function score				
SCR only	99% (161)	93% (152)	82% (134)	74% (121)
SCR+RCR	100% (17)	100% (17)	82% (14)	88% (15)
ASES Shoulder Index score				
SCR only	99% (161)	93%	82%	74% (121)
SCR+RCR	100% (17)	100% (17)	82% (14)	88% (15)
SANE score				
SCR only	99% (161)	93%	83%	74% (121)
SCR+RCR	100% (17)	100% (17)	82% (14)	88% (15)

NOTE. Number in parenthesis next to percentage is n.

ASES, American Shoulder and Elbow Score; RCR, infraspinatus rotator cuff repair; SANE, Single Assessment Numeric Evaluation; SCR, superior capsule reconstruction; VAS, visual analog score.

improve outcomes, an incorporation of grafts has been observed including repair augmentation,[10] bridging techniques,[10] and more recently SCR.[11-14]

SCR, as described by Mihata et al.,[11] is designed to provide a static restraint to superior migration of the humeral head.[26] Excellent clinical outcomes were reported in the original patient cohort, in whom partial repair of the infraspinatus tendon was performed whenever possible,[11] thus restoring force–couple mechanics. Subsequent articles have reported variability in patient selection and surgical technique, including the concomitant pRCR.[12-14] The inability to restore normal biomechanics in patients with an irreparable infraspinatus tendon may be a factor contributing to the high variability in patient-reported outcome measures, graft retear rates, and reoperations following SCR.[12-14]

The purpose of this study was to evaluate the role of concomitant pRCR (i.e., infraspinatus) on patient-reported clinical outcomes following SCR. We hypothesized that patients who underwent concomitant pRCR of the infraspinatus with SCR would have improved outcomes (American Shoulder and Elbow Surgeons [ASES] Function, ASES Index, and Single Assessment Numeric Evaluation [SANE] scores) when compared with those who underwent SCR alone.

Methods

Study Design

The duration of the study was 2 years. Inclusion criteria consisted of if a patient had an SCR surgery with or without a concomitant infraspinatus repair. Patients were excluded if they lacked at least 6 months of follow-up and/or they did not complete the preoperative baseline questionnaire.

Surgical Outcomes System Database

After approval from the institutional review board (protocol number 2011P002663), a retrospective analysis of a multicenter, prospective outcomes registry database (Surgical Outcomes System) was performed (Arthrex, Naples, FL). After they provided consent for participation, patients received 7 surveys via e-mail over the course of 2 years at select time intervals assessing patient-reported outcome measures regarding pain, range of motion, and functional scores. Operative details from each surgery were entered into the patient's Surgical Outcomes System record by the care team. Aside from a preoperative survey, patients received questionnaires at 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years. Outcomes measured included patients' visual analog scale (VAS) on a scale of 0 to 10, ASES Functional, ASES Index, and SANE score. Patients were excluded if they did not complete a preoperative baseline surgery questionnaire or did not have at least 6 months of follow-up in the database. Response compliance is summarized in Table 1.

Patient Demographics

There were no significant differences between the demographics of the 2 cohorts for sex, ethnicity, race, smoking status, diabetes diagnosis, insurance coverage, age, or body mass index. The demographic information is summarized in Table 2.

Surgical Details

Procedural information is summarized in Table 3.[27] In both groups, the majority of patients had chronic rotator cuff tears, poor rotator cuff quality, and massive tears per Cofield classification.[27] The group that received concomitant infraspinatus repair had a significantly greater number of torn tendons than compared with the group that just underwent SCR alone.

Statistical Analysis

Descriptive statistics were used for overall outcomes and relevant comparisons between the SCR alone and concomitant SCR+RCR. For dichotomous variables and

Table 2. Study Population Demographics

	SCR Only (n = 163)	SCR+RCR (n = 17)
Sex		
Male	61% (99)	59% (10)
Female	35% (57)	18% (3)
Unlisted	4% (7)	24% (4)
Tobacco use		
Nonsmoker	48% (78)	71% (12)
Smoker	10% (16)	0% (0)
Unlisted	42% (69)	29% (5)
Diabetes		
Nondiabetic	54% (87)	65% (11)
Diabetic	4% (7)	12% (2)
Unlisted	42% (69)	24% (4)
Worker's compensation		
No worker's compensation	45% (73)	76% (13)
Worker's compensation	13% (21)	0% (0)
Unlisted	42% (69)	24% (4)
BMI ($P > .05$)	30.7 (SD 6.9)	31.2 (SD 9.5)
Age, y ($P > .05$)	59.8 (SD 8.4)	59.4 (SD 8.1)

NOTE. Number in parenthesis next to percentage is n.
BMI, body mass index; RCR, infraspinatus rotator cuff repair; SCR, superior capsule reconstruction; SD, standard deviation.

Table 4. Preoperative Versus Postoperative (Two-Year) PROMs in all SCR and SCR With RCR (SCR+RCR) Groups

	SCR Only	SCR+RCR
VAS Pain Score		
Preoperative	4.7	4.8
Postoperative	1.6	1.0
P value	$6.2 \times 10^{-20*}$	$1.2 \times 10^{-5*}$
ASES Shoulder Function score		
Preoperative	13.1	13.6
Postoperative	21.7	25.5
P value	$1.1 \times 10^{-24*}$	$2.1 \times 10^{-7*}$
ASES Shoulder Index score		
Preoperative	49.9	48.6
Postoperative	78.2	87.6
P value	$9.4 \times 10^{-28*}$	$3.6 \times 10^{-8*}$
SANE score		
Preoperative	32.0	37.9
Postoperative	64.2	75.5
P value	$4.8 \times 10^{-24*}$	$2.6 \times 10^{-5*}$

ASES, American Shoulder and Elbow Score; RCR, infraspinatus rotator cuff repair; SANE, Single Assessment Numeric Evaluation; SCR, superior capsule reconstruction; SD, standard deviation; VAS, visual analog score.
*$P < .001$.

continuous variables, the Fisher exact test and the Student *t* test with unequal variances were used, respectively. *P* value <.05 was considered statistically significant. A sample size calculation was performed using standard deviation for 1-year post-SCR ASES scores (22.0),[14] substantial clinical benefit (SCB) for 1-year post-RCR ASES scores (17.5),[28] power of 0.80, and alpha of 0.05. The resulting sample size was identified as 15 participants per group. Subanalyses assessing the association between surgical group and proportion of participants meeting SCB for ASES and SANE was performed using either χ^2 tests for association or Fisher exact tests.

Table 3. Concomitant Procedures and Rotator Cuff Description

	SCR Only (n = 163)	SCR+RCR (n = 17)
Concomitant procedures		
Unaltered biceps or debridement	6% (10)	18% (4)
Tenotomy or tenodesis	10% (16)	41% (7)
Suprascapular nerve release	1% (2)	6% (1)
Subacromial decompression	67% (109)	41% (7)
Subscapularis repair	0% (0)	24% (4)
Rotator cuff quality		
Poor	49% (80)	59% (10)
Fair	5% (8)	35% (6)
Good	2% (3)	0% (0)
Unlisted	44% (72)	6% (1)
Cofield tear size classification[27]		
Medium	1% (2)	0% (0)
Large	4% (7)	12% (2)
Massive	40% (65)	76% (13)
Unlisted	55% (90)	12% (2)
Number of tendons torn ($P < .001$)	2.2 (SD 0.61)	2.75 (SD 0.44)

NOTE. Number in parenthesis next to percentage is n.
RCR, infraspinatus rotator cuff repair; SCR, superior capsule reconstruction; SD, standard deviation.

Results

Outcome Measures

A total of 180 patients were included in the study. There were 163 patients who underwent SCR alone and 17 patients who underwent SCR+RCR. Compared with the respective preoperative values, both procedures had significant improvements at 2 years in VAS pain, ASES Shoulder Function, ASES Shoulder Index, and SANE score (Table 4).

For VAS pain scores, both groups demonstrated a trend of decreasing over the study's 2 years (Fig 1). There was no difference in pain scores preoperatively or at 3 months and 6 months (Table 5). However, patients with a concomitant infraspinatus repair had lower pain scores at 6 months, 1 year, and 2 years, with scores significantly lower at 1 year ($P = .04$).

For ASES Shoulder Function and Shoulder Index scores, both groups increased over time (Fig 2). Compared with those who only underwent SCR, patients who also received an infraspinatus repair had significantly greater ASES Shoulder Function and Shoulder Index scores at both 1 year ($P = .03$) and 2 years ($P = .02$) (Table 5).

SANE score increased over 2 years (Fig 3). Patients who underwent the additional infraspinatus repair had no significant improvement in SANE score at 6 months,

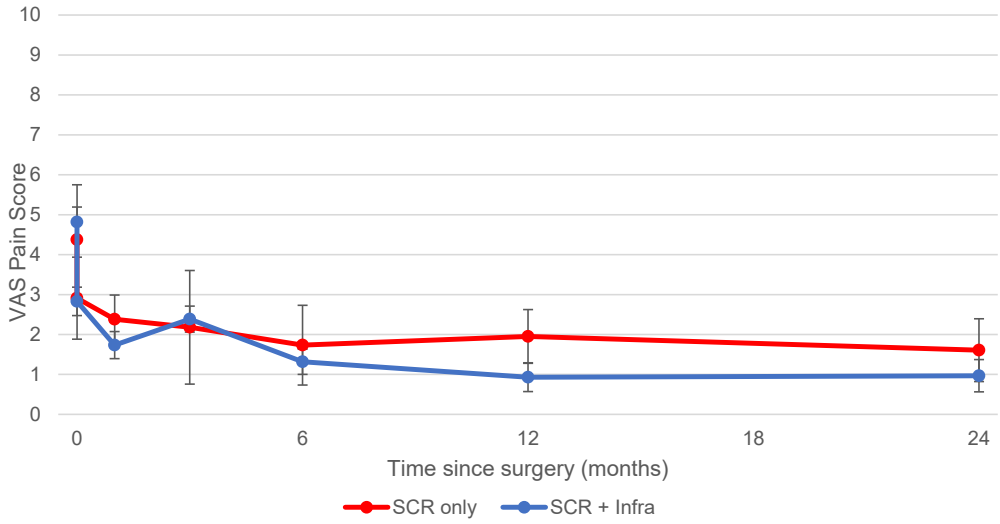

Fig 1. VAS Pain Score for SCR only versus SCR and RCR. Error bars indicate 95% confidence intervals. (RCR, infraspinatus rotator cuff repair; SCR, superior capsule reconstruction; VAS, visual analog score.)

1 year, and 2 years when compared with SCR alone (Table 5).

A greater proportion of patients who underwent SCR+RCR (92.9%) met or exceeded SCB for ASES scores at 1-year postoperatively compared with SCR alone (60.4%; $P = .017$), with no differences identified at 2 years ($P = .520$) postoperatively. Moreover, no differences were noted between surgical groups in the proportion of patients meeting or exceeding SCB for SANE scores 12 months ($P = .222$) and 2 years ($P = .112$) postoperatively.

Discussion

This study demonstrates that SCR provides postoperative improvement in pain and function at 1 and 2 years. Patients who underwent concomitant infraspinatus repair demonstrated significantly greater ASES Index (87.6 vs 78.2, $P < .05$) and ASES Function (25.5 vs 21.7, $P = .02$) scores than compared with those who underwent SCR alone. SANE scores showed a nonsignificant difference between SCR+RCR and SCR alone (75.5 vs 64.2, $P = .07$).

Although SCR can provide significantly improved pain and functional outcomes, there has been considerable variability in the success of this intervention.[12-14,22,29,30] A multitude of factors are likely contributing to this variability, including patient selection, surgical technique, and concomitant procedures. As this technique gains popularity, so too does the need to accurately identify and define the factors predictive of an improved and reliable outcome. In this study, SCR was shown to provide modest improvement in pain and function in patients with irreparable rotator cuff tears. However, patients who underwent concomitant repair of the infraspinatus tendon demonstrated significantly improved patient-reported outcome measures at 2 years postoperatively when compared with patients who underwent SCR alone. This is despite the cohort of patients undergoing infraspinatus repair having a statistically larger tear size.

SCR was first described by Mihata et al.[11] in 2003 as a means to treat irreparable rotator cuff tears. In the initial series of 24 patients, 87.3% of patients demonstrated an intact graft at a mean of 34.1 months follow-up with significantly improved forward elevation, external rotation, and ASES scores. The authors recommended repair of the infraspinatus tendon followed

Table 5. Comparison of PROMs in SCR Versus SCR with RCR (SCR+RCR) Groups

	Preoperative	3 Months	6 Months	1 Year	2 Years
VAS Pain Score					
SCR only	4.4	2.2	1.7	2.0	1.6
SCR+RCR	4.8	2.4	1.3	0.9	1.0
P value	.24	.35	.21	.04*	.14
ASES Shoulder Function score					
SCR only	13.1	14.8	18.8	20.3	21.7
SCR+RCR	13.6	12.1	19.2	23.8	25.5
P value	.36	.05	.41	.03*	.02*
ASES Shoulder Index score					
SCR only	49.9	63.7	72.8	74.3	78.2
SCR+RCR	48.6	59.4	75.5	85.0	87.6
P value	.39	.17	.29	.03*	.048*
SANE score					
SCR only	32.0	45.6	57.9	62.7	64.2
SCR+RCR	37.9	35.9	63.6	72.8	75.5
P value	.13	.050	.18	.09	.07

ASES, American Shoulder and Elbow Score; PROMs, patient-reported outcome measures; RCR, infraspinatus rotator cuff repair; SANE, Single Assessment Numeric Evaluation; SCR, superior capsule reconstruction; SD, standard deviation; VAS, visual analog score.

*$P < .05$.

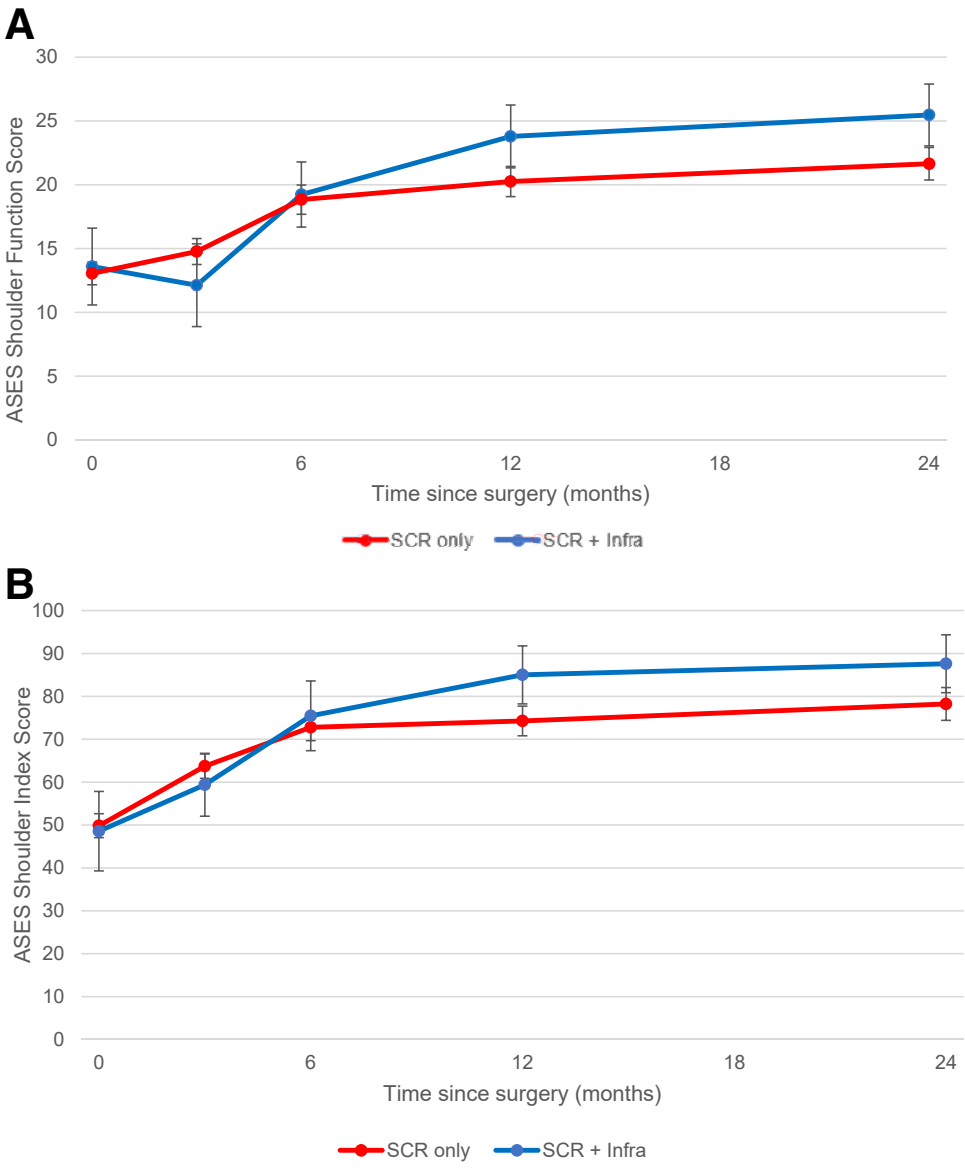

Fig 2. ASES Function (A) and Index (B) scores for SCR only versus SCR and RCR. Error bars indicate 95% confidence intervals. (ASES, American Shoulder and Elbow Score; RCR, infraspinatus rotator cuff repair; SCR, superior capsule reconstruction.)

by SCR using a thick fascia lata autograft with side-to-side sutures to the infraspinatus. Biomechanical evaluation of SCR for isolated supraspinatus tendon defects has validated the aforementioned technique to prevent superior migration of the humeral head (similar to the intact supraspinatus tendon),[26] particularly when performed combined with an infraspinatus partial repair.[26] Subsequent clinical studies have supported the need for the infraspinatus repair and integrity of the posterosuperior rotator cuff.[13,31,32]

In recent years, surgeons have evolved this technique to use allograft, thinner grafts, and variability in concomitant procedures.[13,14,33,34] Many of these factors have likely contributed to the large variability in clinical outcomes and failure rates.[12-14,33-35] The first large multicenter study on the dermal allograft demonstrated these considerations. Denard et al.[14] analyzed 59 patients undergoing SCR with dermal allografts, demonstrating improvements in the patients' pain and functional outcomes measures. However, there was a 19% rate of revision surgery and only 45% of grafts demonstrated complete healing. Although some studies have shown promising outcomes,[12] others have shown clinical failure rates up to 65%[13] and retear rates up to 70%.[35] As with the autografts, the infraspinatus integrity played an important role, with a clinical failure rate of 84% in patients with infraspinatus tendons grade II-IV fatty infiltration based on Goutallier grade.[36] Given that SCR is a static restraint designed to depress the humeral head, its inability to restore the posterior force couple may limit the effectiveness of SCR in managing massive tears where the infraspinatus is truly

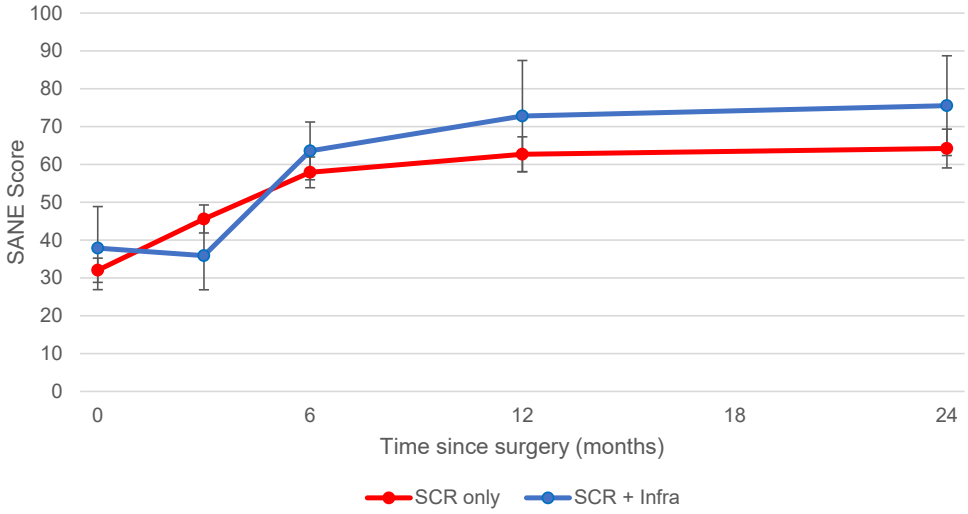

Fig 3. SANE for SCR only versus SCR and RCR. Error bars indicate 95% confidence intervals. (RCR, infraspinatus rotator cuff repair; SANE, Single Assessment Numeric Evaluation; SCR, superior capsule reconstruction.)

irreparable. These findings are supported in the current study, with improved outcomes in patients who underwent SCR in combination with infraspinatus repair and a greater proportion of patients reaching SCB for ASES scores at 1 year postoperatively compared with SCR alone.

Repair of the infraspinatus as a treatment for massive irreparable rotator cuff tears is a well-accepted and widely adopted intervention first described by Burkhart et al.[37] in 1994. The intervention was proposed to restore the anteroposterior force couples, thus restoring the "suspension bridge" effect to the shoulder resulting in improved biomechanics.[23,37] Several studies have demonstrated significantly improved pain, range of motion, and functional outcomes following partial rotator cuff repair supporting the force—couple theory.[9,24,25,38] In the current study, dynamic restoration of the anteroposterior force—couple (i.e., pRCR) was combined with static restraint to superior migration (i.e., SCR) resulting in continuously improving outcomes at 2 years postoperatively, contradicting the deteriorating outcomes observed following partial repair alone.[25] Thus, these seemingly independent interventions may have a synergistic effect with the humeral head depression imposed by SCR acting to recenter the humeral head and detension the infraspinatus repair, protecting its function and integrity over time. This concept has also been demonstrated in biomechanical[26] and clinical[13,31,32] studies of SCR. In the setting of an irreparable infraspinatus alone or in combination with teres minor, surgeons should potentially consider other salvage procedures, such as arthroscopic-assisted tendon transfers[15-21] or reverse shoulder arthroplasties.[39-41]

Recovery curves are becoming increasingly important in understanding the process of recovery following shoulder surgery. Interestingly, the postoperative recovery curves referenced in this study demonstrate a delayed early recovery when a concomitant infraspinatus repair was performed. However, patients who underwent infraspinatus repair demonstrated greater patient-reported outcome measures for all variables by 6 months postoperatively with statistically significant values being observed for VAS, ASES Function, and ASES Index by 1-year postoperatively. This delayed early recovery with improved long-term prognosis when infraspinatus repair is performed is important for both surgeons and patients to understand.

Limitations

Several limitations should be considered when interpreting the data presented in this study. First, factors relating to surgical technique, intra or postoperative complications, reoperations, revision surgery, radiographic outcomes, or range of motion were not captured and reported. Second, the lack of a physical follow-up is a major limitation. Third, there were a disproportionate number of concomitant procedures and worker's compensation patients between the 2 groups. Fourth, the number of patients in the SCR+RCR group was limited to 17 patients. Although this met the intended sample size for the primary outcome (ASES), it may have been underpowered for the secondary outcomes evaluated. This may explain the failure to reach a statistical significance for SANE scores. Finally, as is inherent to all database studies, the accuracy of the information reported is depended on the completeness of data entry, the accuracy of the coding of each surgical procedure, the surgeries were performed by multiple surgeons, and the surgical technique was not standardized throughout the patient cohort.

Conclusions

SCR provides modest improvements in pain and function at 1 and 2 years postoperatively in patients with irreparable rotator cuff tears. Patients who underwent SCR and concomitant infraspinatus repair demonstrated significantly improved ASES Index and ASES Function scores and statistically nonsignificant improvement in SANE scores at 24 months postoperatively when compared with SCR alone.

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