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Superior Capsular Reconstruction: An Evidence-Based Review

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Abstract

Purpose: To perform a systematic review of superior capsular reconstruction to establish whether patients experience clinical and radiographic improvement.

Methods: Clinical studies were found through a PubMed search. Only those examining clinical and radiographic outcomes following superior capsular reconstruction were included.

Results: Patient functional outcome scores for both ASES shoulder score and VAS scores experienced a mean improvement of 42.71 (P< .00001) and 2.7 (P <.0001), respectively. Radiographic outcomes measuring acromiohumeral distance experienced a mean improvement of 2.0 mm (P<.001). Patient shoulder range of motion including forward flexion, external rotation, and abduction experienced an overall mean improvement by 37.8 degrees (P< .0001), 13.3 degrees (P< .0001), and 56.9 degrees (P< .005), respectively.

Conclusion: With significant clinical and radiographic improvements experienced by patients in this systematic review, superior capsular reconstruction is supported as an effective, beneficial surgery for patients.

Level of Evidence: III

Keywords: Irreparable rotator cuff tear; Massive rotator cuff tear; Rotator cuff tear; SCR surgery; Superior Capsular Reconstruction

Introduction

Rotator cuff injuries are the most common cause of symptomatic shoulder disorders and have been reported as occurring in up to 34% of individuals **[1, 2]**. Risk factors for rotator cuff tear include advanced age, history of trauma, tobacco use, hypercholesterolemia, and dominant arm usage **[3-5]**. Furthermore, a recent genome-wide association study by Roos, et al. revealed genetic loci associated with a predisposition to rotator cuff tear **[6]**. One of the key functions of the rotator cuff is to prevent superior migration of the humeral head. Migration of the humeral head leads to decreased acromiohumeral distance (AHD) **[7]**. A decreased AHD is accompanied by limited active range of motion (ROM), impaired muscle strength, and shoulder pain **[8]**.

For those patients who elect to pursue surgical management, arthroscopic rotator cuff repair can be a viable option. However, in some cases of massive rotator cuff tear (>5cm), retraction (>5cm), and/or advanced fatty degeneration of the rotator cuff muscle (Goutallier grade 3 or 4), arthroscopic repair may not be effective **[9, 10]**. In these cases, traditional repair methods may be insufficient to restore function, can lead to complications involving permanent damage of the glenohumeral joint, and have high rates of retear **[11]**.

While older patients have seen adequate results with reverse total shoulder arthroplasty (RTSA), younger patients treated with an RTSA have a high complication rate due to greater functional expectations and activity demand **[7, 9, 12]**. Latissimus dorsi transfer, pectoralis major transfer, hemiarthroplasty, debridement and subacromial decompression, partial repair, and biceps tenotomy have all been proposed treatment options with varying results **[10,13]**.

First proposed by Mihata in 2012, arthroscopic superior capsular reconstruction (SCR) is a technique in which a surgeon attaches a patch graft between the superior aspect of the glenoid and the rotator cuff footprint of the greater tuberosity of the humerus, preventing the superior migration of the humeral head and acting as a cushion against the coracoacromial ligament **[8,14,15]**. Both fascia lata autografts and acellular dermal autografts have been used successfully for this technique **[8, 9]**. This procedure has been shown to adequately restore glenohumeral stability with graft tear rates of less than 17% at 2-year follow-up, making SCR a reliable and useful treatment for irreparable rotator cuff tears **[8]**. Our goal is to provide a systematic review of the literature, highlighting a viable treatment option for patients with irreparable rotator cuff tears. By reviewing the current literature on superior capsular reconstruction, we hope to provide evidence for its efficacy in treating a subset of rotator cuff tears in which previous surgical options have been plagued with unpredictable results.

Methods

A Pubmed literature search was conducted using the keywords "superior capsular reconstruction" in July 2018. This search yielded 117 articles. Only full text English language articles were screened for eligibility criteria. Review articles, surgical technique articles, and case reports were excluded. Following exclusion, 6 articles met criteria for inclusion in this review.

Results

Functional Outcome Scores

Functional outcomes of the 6 studies included in this review used the American Shoulder and Elbow Surgeons (ASES) scale. The ASES includes both an objective physician assessment and a subjective patient-rated component, weighted at 50% for both pain and function respectively. Our analysis of the 6 studies identified 308 total patients with ASES scoring available. This patient population had a mean age of 62.9 years, with mean follow-up of 28.2 months. Following SCR surgery, there was a mean improvement of 42.71 (P< .00001) on the ASES scale, with a mean preoperative ASES shoulder score of 42.7 (range 23.5-52.2) and a mean postoperative ASES shoulder score of 85.4 (range 77.5- 92.9).

Additionally, four reviewed studies reported visual analogue scale (VAS) scores, which is a unidimensional tool for assessing pain intensity. In total, 185 patients were assessed using this scale, with a mean age of 62 and a mean follow-up of 21.7 months.Overall, there was a mean VAS score improvement of 2.7 (P <.0001). There was a mean preoperative VAS score of 4.0 (range 4.0-6.3) and a mean postoperative VAS score of 1.3 **(Table 1)**.

Article Title	Author	Outcomes Measured
Arthroscopic Superior Capsular Reconstruction With Acellular Dermal Allograft for the Treatment of Massive Irreparable Rotator Cuff Tears: Short-Term Clinical Outcomes and the Radiographic Parameter of Superior Capsular Distance	Pennington WT et al. **[9]**	VAS score; ASES score; AHD interval; forward flexion, abduction,
Can inadequate acromiohumeral distance improvement and poor posterior remnant tissue be the predictive factors of re-tear? Preliminary outcomes of arthroscopic superior capsular reconstruction	Lee SJ et al. **[7]**	VAS score; ASES score; AHD interval; forward flexion; external rotation;
Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears.	Mihata et al. **[8]**	ASES score; AHD interval; forward flexion; external rotation; abduction
Preliminary Results of Arthroscopic Superior Capsule Reconstruction with Dermal Allograft.	Denard PJ et al. **[23]**	VAS score; ASES score; AHD interval; external rotation
Superior Capsular Reconstruction: Clinical Outcomes After Minimum 2-Year Follow-Up.	Hirahara AM **[26]**	VAS score; ASES score
Return to Sports and Physical Work After Arthroscopic Superior Capsule Reconstruction Among Patients With Irreparable Rotator Cuff Tears.	Mihata et al. **[30]**	ASES score; forward flexion; external rotation;

Table 1: This table summarizes the main outcomes reported in the articles analyzed for this systematic review.

Radiographic Outcomes

Acromiohumeral distance (AHD) is a measurement from the inferior aspect of the acromion to the apex of the humeral head. 4 studies included in this review measured AHD,comprising a total of 176 patients.Average patient age was 62 with an average follow up of 24 months.Across these studies, patients experienced a mean improvement of 2.0 mm (P<.001). The mean preoperative AHD was 6.5 mm (range 4.5-7.1 mm) and the mean postoperative AHD was 8.5 mm.

Shoulder Range of Motion

Forward flexion range of motion was examined in 4 studies. In total, data was available for 200 patients, with a mean age of 62.2 and a mean follow up of 22.2 months. The overall improvement in range of motion was 37.8 degrees (P< .0001). The mean preoperative forward flexion range of motion was 117 degrees (range 84-130º) and the mean postoperative forward flexion range of motion was 154.7 degrees (range 139.5-160º).

External rotation range of motion was also examined in 4 studies.In total, data was available for 214 patients, with a mean age of 64.7 and a mean follow up of 31.1 months. The overall improvement in range of motion was 13.3 degrees (P< .0001). The mean preoperative external rotation range of motion was 31 degrees (range 26-40.8º) and the mean postoperative forward flexion range of motion was 44.3 degrees (range 40-53.7º).

Abduction range of motion was examined in 2 studies.In total, data was available for 186 patient, with a mean age of 63.2 and a mean follow up of 30 months. The overall improvement in range of motion was 56.9 degrees (P< .005). The mean preoperative abduction range of motion was 97.1 degrees (range 92-103º) and the mean postoperative abduction range of motion was 154 degrees (range 150-159º).

A 2018 study by Simovitchet al. determined the minimal clinically important difference (MCID) for patient outcome scores and range of motion in patients who underwent total shoulder and reverse total shoulder arthroplasty **[16]**. The calculated MCID for abduction, forward flexion, and external rotation was determined to be 7+/- 4 degrees, 12+/- 4 degrees, and 3 +/- 2 degrees respectively **[16]**. According to this criteria for MCID, the mean improvement for range of motion experienced by the patients in this systematic review met minimal improvement necessary for a patient to achieve an outcome that is clinically meaningful.

Surgical Technique

Multiple portal setups for SCR includemidlateral, juxta-acromial, anterior, and posterior portal positioning. Lateral decubitus or beach chair position may be used with shoulder abduction ranging from 30-45 degrees. The preparation for graft fixation involves abrading and drilling both the superior glenoid rim and the rotator cuff muscle footprint. Two medial row anchors with suture tapes are placed in the medial row of the humerus, and 3 suture tapes are placed through the medial aspect of the graft. The graft may be an acellular dermal allograft or a tensor fascia lata autograft from the ipsilateral leg. The graft measurements are obtained using a probe based on medial to lateral and anterior to posterior measurements. It is recommended to measure 15mm medial to the superior glenoid edge to the lateral aspect of the greater tuberosity with an extra 5mm added to account for a 10mm superior glenoid footprint. If autograft is used, its harvested size is typically 2-3 times the measured defect and is folded on itself 2-3 times to obtain the desired thickness of approximately 6-8mm **[15]**. Holes are placed medially and laterally in the graft to allow passage of sutures corresponding to anchor placement corresponding to the superior glenoid and the proximal humerus.

Insertion of the graft can utilize either the double pulley or the push-in anchor technique **[9]**. Push-in anchor technique allows the use of the anchor suture tape configuration to push the graft through the juxta-acromial portal. Two or three anchors are used on the glenoid, and the medial aspect of the graft is secured to the superior glenoid. Next, the lateral aspect of the graft is secured to the proximal humerus footprint with either a single or double row technique. Standard knot-tying or knotless anchors may be utilized for graft fixation. Supplemental fixation with side to side margin sutures can be achieved by securing the posterior aspect of the graft to the intact infraspinatus and teres minor. Another margin suture can be applied by fixing the anterior aspect of the graft to the superior margin of the intact subscapularis or supraspinatus.

Discussion

Commonly accepted definitions of massive rotator cuff tears include tears measured at >5cm, retraction (>5cm), and/or advanced fatty degeneration of the rotator cuff muscle (Goutallier grade 3 or 4) **[9, 10]**. Another definition by Zumstein, et al. defined a massive tear as any tear involving complete detachment of 2 or more tendons **[17]**. When the tendon tissue has appropriate integrity, even massive tears are able to be repaired surgically **[18]**. However, when the tissue quality is poor, the tears are deemed irreparable **[18]**. These irreparable rotator cuff tears have a defect in the superior capsule which causes an uncoupling of forces across the glenohumeral joint **[8, 19]**. Irreparable characteristics include static superior migration of the humeral head, a narrowed or absent acromiohumeral interval, and fatty infiltration affecting 50% of the rotator cuff musculature **[10]**. The tears present a challenge to surgeons, who must attempt to recreate normal kinematics of the shoulder **[19]**. The massive, irreparable tears cause limited arm elevation, pain, muscle weakness and eventual muscle atrophy **[8, 19]**.

Several treatment options have been described previously for massive RCT repair including reverse total shoulder arthroplasty and tendon transfers, with varying rates of success

[20]. When a patient has minimal arthritis and is relatively young (<65 years old), superior capsular reconstruction (SCR) increases functional outcomes, ROM, and AHD by effectively restoring normal shoulder kinematics.

In this systematic review, we extracted patient outcome scores including VAS pain scores and ASES shoulder scores. We further summarized functional outcomes with regards to improvements in ROM. Finally, we looked at radiographic outcomes in the form of acromiohumeral distance (AHD). The goal of this review is to summarize the outcomes of 6 studies on arthroscopic superior capsular reconstruction (ASCR) and explain why achieving near anatomic AHD postoperatively leads to better outcomes and scores among the ASCR population.

Of the 6 studies introduced in this systematic review, 4 studies comprising 185 patients reported VAS scores. In all 4 studies, there was statistically significant improvement. Preoperative scores ranged from 4.03 to 6.25, while postoperative VAS scores ranged from 0.38 to 1.7. The most significant improvement in VAS with the widest margin was observed in the 2017 Hirahara study, wherein the mean pre-operative VAS was 6.25 and post-operative VAS 0.38 over a 2-year follow-up period **[20]**. Notably, however, this study included only 9 patients.

All 6 studies also demonstrated improvement in ASES scores ranging from a mean increase of 23.5 to 97. All studies showed statistically significant improvement with the 2013 Mihata study demonstrating the most significant range of improvement of 23.5 to 92.9.

Pre- versus post-operative ROM was also measured. Four studies encompassing 200 patients looked at forward flexion. Four studies involving a total of 214 patients measured external rotation. Two studies totaling 186 patients also included abduction. All ranges of motion tested demonstrated statistically significant improvements. Forward flexion increased from 84-130 degrees pre-operatively, to 139.5-160 degrees postoperatively. External rotation improved from 26-40.8 degrees preoperatively to 40-53.7 degrees postoperatively. Abduction also improved from 92-103 degrees preoperatively to 150-159 degrees postoperatively.

As previously stated in our results, our systematic review demonstrates not only statistically significant, but also clinically relevant results by meeting minimal clinically important difference criteria (MCID) outlined by Simovitch in 2017 for range of motion **[16]**. Although originally established as a measurement of clinically meaningful differences in ROM after total shoulder arthroplasty, changes in ROM are an important outcome measurement in all shoulder procedures. All of our analyzed studies met MCID for abduction (7+/- 4 degrees), forward flexion (12 +/- 4 degrees), and external rotation (3 +/- 2 degrees) as outlined above.

Finally, radiographic outcomes were assessed in the form of acromiohumeral distance. A study by Weiner and Macnab in 1970 investigated superior migration of the humeral head using plain AP radiographs **[21]**. They concluded that the normal distance was found to be between 7- 14 mm in patients with intact rotator cuff muscles. Less than 7 mm was associated with some form of rotator cuff pathology. Saupeet al. in 2006 again investigated the association between rotator cuff tears and AHD, where they reported an average acromiohumeral distance in intact shoulders of 10.5 mm **[22]**. In this systematic review, we found that AHD was measured in 176 patients across 4 of the 6 studies presented. The mean pre-operative AHD was 6.5 mm (range 4.5- 7.1) and the mean postoperative AHD was 8.5 mm. All but one study showed statistically significant improvement in AHD after SCR. Denard, et al. did not show statistically significant values in AHD when comparing pre-versus postoperative values (p = 0.889 **[23]**. However, Denard, et al. went on to explain this discrepancy by acknowledging that their radiographs were not fluoroscopically controlled, representing a limitation to this aspect of their study **[23].**

The significance of AHD cannot be overstated with regards to establishing properly functioning glenohumeral (GH) joint and positive outcomes in ASCR. We posit that achieving near anatomic AHD will lead to improved GH joint mechanics and better clinical outcomes. The native GH joint mechanics are maintained by both the deltoid muscle and all rotator cuff muscles working in conjunction. Force coupling in coronal, and transverse planes are achieved by maintaining reduction of the humeral head on the glenoid. When a massive, irreparable tear is present, the force coupling of the glenohumeral joint is changed, and the humeral head is no longer able to remain reduced throughout GH joint ROM.

In 1992, Burkhart observed three distinct kinematic patterns based on GH motion when large to massive RTC tears are present. Stable fulcrum kinematics, when present, allowed the preservation of force coupling in the coronal and transverse planes and subsequently patients with these kinematics had full strength and normal motion **[24]**. Unstable fulcrum kinematics involved an almost complete tear of both the superior and posterior rotator cuff; subsequently, active range of motion was limited to a shoulder shrug in patients with these kinematics. Finally, captured fulcrum kinematics were demonstrated in shoulders with tears of the supraspinatus, greater than one-third of posterior rotator cuff, and at least half of the subscapularis. The massive tear resulted in superior migration of the humeral head. However, a fulcrum was established at the acromion or anterior deltoid origin, allowing patients some active elevation of the shoulder **[24]**.

Arthroscopic SCR attempts to preserve stable fulcrum kinematics and subsequent force coupling in the coronal and transverse planes, which leads to optimal GH motion and results. Thompson, et al. (1996) confirmed that during abduction, small translations of the humeral head occur about the coronal, sagittal, and transverse planes. Further, the forces generated by the rotator cuff act to center the humeral head in the glenohumeral joint leading to balanced forces across the joint. The subscapularis transverse moment is countered by the transverse moment of the teres minor and infraspinatus, resulting in a reduced, balanced humeral head in the GH joint. The balanced forces have effectively been coined transverse force couple. When a substantial portion of either the anterior or posterior aspect of the transverse force couple is disrupted, the fulcrum about which the GH joint functions is disrupted, leading to impaired GH joint function and superior migration of the humeral head. The superior migration will lead to decreased AHD and subacromial impingement **[25].** However, when an ASCR is successfully performed, the AHD approximates normal parameters (7-14 mm) **[21]**. The ASCR essentially takes on the function of the transverse force couple, effectively maintaining humeral head reduction in the GH joint, and allowing optimal function and decreased pain.

Highlighting our belief in the importance of establishing a normal AHD, in 2018 Lee, et al. analyzed 36 shoulders treated with ASCR with an average follow up of 24.8 +/- 6.9 months **[7]**. Specifically, Lee analyzed AHD as a key factor of biomechanical stability and clinical outcomes. Statistically significant improvements in the VAS, forward flexion, ASES, and constant score were all observed in the non-retear group (23 patients) **[7]**. The non-retear group also had the AHD increase from 5.1 +/- 1.9 pre-op to 8.9 +/-2.0 post-op **[7]**. As expected, inferior results were seen in the re-tear group (13 patients), which had a mean pre-operative AHD of 4.7+/-2.8 and a mean post-op AHD of 6.9 +/- 2.5 **[7]**. This suboptimal outcome further suggests superior clinical results concomitant with a greater AHD post-operatively.

Of the 6 articles reviewed, not all reported on the parameters we reviewed. Two studies did not report VAS, one study did not report range of motion, and one study did not report AHD. All studies did, however, report on ASES. Another limitation of this review is that of the 6 studies, 3 used fascia lata autograft, while the other 3 used dermal allograft. Dermal allograft was shown in Denard, et al. as having decreased morbidity, as well as decreased operative times when compared to fascia lata autograft **[23]**. It is also noted in Hirahara, et al. that dermal autograft has the potential to incorporate as host tissue, as evidenced by the presence of vasculature on follow-up imaging **[26]**. This is not the case with fascia lata autograft, which therefore may lead to further complications postoperatively which were not examined in these studies.

Several pitfalls of ASCR were noted in the Denard, et al. study, with subsequent case pearls to improve the complications found on patient follow-up outlined **[23]**. Some recommendations include optimizing graft thickness to 3 mm (normal superior capsule thickness ranges from 4.4 to 9.1 mm), limiting SCR to those who categorically fall within the radiographic Hamada classification of 1 and 2, and delaying strengthening post-operatively from 12 to16 weeks, to name a few **[27-29]**. In addition to the shortcomings noted previously in this review, reviewed studies noted further pitfalls and limitations including short follow-up times and a non-randomized retrospective data collection methodology.

Conclusion

Arthroscopic SCR has demonstrated improved functional scores, restored shoulder kinematics, improved function, and has been shown to be a viable option for patients returning to physical work or sports related activity. The above summarized results support SCR as a viable option when considering treatment of massive or irreparable rotator cuff tears refractory to repair. We also maintain that SCR ultimately optimizes function and decreases pain by restoring AHD to normal parameters. Consequently, when AHD is not approximated to normal anatomic distance, there is a direct correlation to the rate of SCR failure. In summary, ASCR provides clinically significant reductions in pain, restored AHD, and significantly improved shoulder functionality.

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