Orthopaedics & Traumatology: Surgery & Research 105 (2019) 1535–1542

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Review article

The role of Superior Capsule Reconstruction in the irreparable rotator cuff tear — A systematic review

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ARTICLE INFO

Article history:
Received 9 March 2019
Accepted 19 July 2019

Keywords:
Shoulder
Massive rotator cuff repair
Irreparable rotator cuff repair
Superior capsule reconstruction

ABSTRACT

Background: Irreparable rotator cuff tears in active patients provide a significant challenge and a consensus on the gold standard treatment is currently lacking. Superior capsule reconstruction (SCR) has recently been advocated and functions by providing a passive biological constraint to superior humeral head migration. The aim of this study is to systematically review the literature to evaluate the role of SCR in terms of functional outcome scores and failure rates.
Patients and methods: A review of the online databases Medline and EMBASE was conducted in accordance with the PRISMA guidelines on the 28th January 2019. Clinical studies reporting SCR using any type of graft or surgical technique were included if reporting either functional outcome scores or rate of secondary surgery. The studies were appraised using the Methodological index for non-randomised studies tool.
Results: The search strategy identified nine studies eligible for inclusion; five reported on fascia lata autografts and four studies reported on dermal allografts. All nine studies reported significant improvement in functional scores after SCR. Rates of secondary surgery were only provided in the dermal allograft studies at short-term follow-up (mean 10.9 to 32.4 months) and ranged from 0 to 18.6%. Radiological assessment revealed graft failure in 5.5 to 55% of dermal allografts and 4.2 to 36.1% of fascia lata autografts.
Conclusion: This review demonstrates that SCR is a useful treatment modality for patients with irreparable rotator cuff tears. SCR was associated with significantly improved functional outcome scores in all studies. All studies reported a preserved or increased mean AHD. The radiological graft failure rate ranged from 4.2 to 55% and the short duration of follow-up in most studies means that this remains an important concern that requires longer-term evaluation.
Level of evidence: IV, systematic review.

1. Introduction

Rotator cuff tears are a common cause of shoulder pain and dysfunction. Factors to be considered when deciding if a repair is feasible are the tear size, tissue quality and amount of tendon retraction [1]. Repair of massive tears are fraught with high failure rates because of poor tissue quality, difficulty in achieving a repair with minimal tension and the frequent association with poor bone quality [2]. The outcomes of treatment options for young, active patients with massive, retracted rotator cuff tears have historically been considered unpredictable [3]. In addition, static cranial migration of the humeral head, a reduction of the acromiohumeral space, and atrophy and fatty infiltration of more than 50% of the corresponding muscle tissue have been linked to poor outcomes following rotator cuff repair [4,5].

The absence of the rotator cuff disrupts the coronal force couple and alters the mechanics of the glenohumeral joint. The humeral head subsequently migrates superiorly and this frequently results in pain and functional deficits [1]. Surgical options include arthroscopic debridement, balloon spacer arthroplasty, partial cuff repair, rotator cuff grafting and reverse shoulder arthroplasty (RSA). Currently there appears to be no consensus regarding the best option for treating these complex clinical scenarios [6]. Superior capsule reconstruction (SCR) has recently been advocated for this complex group of patients. The procedure functions by providing a passive biological constraint to superior humeral head migration thus restoring a stable fulcrum [7,8]. Early adopters have reported

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https://doi.org/10.1016/j.otsr.2019.07.022
1877-0568/

Table 1
Search strategy for Medline.

Search Number	Search Term	Results
1	Superior capsular reconstruction.mp.	10
2	Superior capsule.mp.	36
3	Superior capsule reconstruction.mp.	13
4	Shoulder joint/or shoulder/or shoulder pain/or shoulder injuries	32,279
5	Rotator Cuff Injuries/or irreparable rotator cuff.mp.	4877
6	1 OR 2 OR 3	43
7	4 OR 5	34,919
8	6 AND 7	36

promising results, but its use remains controversial. Debate exists over the type of graft used, the graft thickness, the importance of posterior margin convergence and the long-term results [9–12].

The aim of this study is to perform a systematic review of the literature in order to define the clinical outcomes of superior capsule reconstruction with respect to functional outcome scores, importance of margin convergence, acromiohumeral distance (AHD), graft failure and rates of secondary surgery. The hypothesis was that SCR would be associated with significant improvement in functional outcome scores and acromiohumeral distance.

2. Materials and methods

A systematic review of the literature was conducted in accordance with the PRISMA guidelines using the online databases Medline and EMBASE. The review was registered on the PROSPERO database on 28th January 2019 (Reference number CRD42019123458). The searches were performed independently by two authors on the 20th of January 2019 and repeated on the 28th of January 2018 to ensure accuracy. Any discrepancies were resolved through discussion between these two authors, with the senior author resolving any residual differences. The Medline search strategy is illustrated in Table 1 and Fig. 1.

Clinical studies published in the English language were considered for eligibility. Cases series or comparative studies reporting on SCR using any type of graft and any surgical technique were included if they reported either functional outcome scores or revision rates. Only primary research was considered for review with any abstracts, comments, review articles and technique articles excluded. The clinical studies were appraised independently by two authors using the Methodological index for non-randomised studies (MINORS) tool [13].

3. Results

Application of the search strategy resulted in inclusion of nine eligible studies and a total study population of 367 SCR's [3,12,14–20]. Five studies reported outcomes of SCR using fascia lata autografts ($n = 201$) [12,14–17] and four studies reported outcomes associated with dermal allografts ($n = 166$) [3,18–20]. Concise details of these studies are provided in Table 2.

3.1. Functional outcome scores

All nine studies reported significant improvements in functional scores after SCR as illustrated in Table 2. Four of the studies using dermal allograft for SCR reported ASES at a mean of 10 to 32 months follow-up, the mean scores ranged from 77.5 to 89 [3,18–20]. Four of the five studies on fascia lata autografts reported the ASES at a mean of 15 to 60 months follow-up with means scores ranging from 73.7 to 92.9 [12,15–17]. The Constant score was reported in three fascia lata autograft studies with mean scores ranging from 63.7 to 82.8 [14–16]. The Subjective shoulder score was reported by two allograft studies (means 76.3 and 91) and one autograft study (mean 70) [14,18,19].

3.2. Secondary surgery

Secondary surgery rates were reported in all four dermal allograft studies [3,18–20] where mean follow-up ranged from 10.9 to 32 months. Denard et al. [19] had the highest rate at 18.6% at a mean of 17.7 months follow-up; 11.9% required conversion to reverse shoulder arthroplasty and 3.4% had a revision SCR. Hirahara et al. [20] similarly reported that 11% of patients required conversion to reverse shoulder arthroplasty at midterm follow-up (mean 32 months). In contrast, Burkhart et al. [18] reported no secondary surgeries in their 10 patients although this group had the shortest follow-up (mean 10.9 months) and Pennington et al. [3] reported a 1.2% conversion rate to RSA due to ongoing pain.

Rates of secondary surgery were not explicitly reported in any of the fascia lata autograft studies [12,14–17]. However, Mihata et al. [12] reported a complication rate of 9% at a mean of 60 months. These complications include severe stiffness requiring arthroscopic release (3.4%), postoperative infection requiring arthroscopic debridement (2.2%) and anchor pull out (3.4%).

3.3. Radiological outcomes

All nine studies reported rates of either graft healing or failure. Details of these results are provided in Table 3. Three studies reported the state of the dermal allografts radiologically [18–20]; Hirahara et al. reported 80% of grafts to be intact at a mean of 32.4 months follow-up [20], Burkhart et al. [18] found 70% of grafts intact at 10.9 months and Denard et al. [19] reported that 45% of grafts were intact at 17.7 months. The final dermal allograft study only imaged patients postoperatively if they were symptomatic and therefore did not provide an overall radiological failure rate [3]. The location of dermal allograft failures varied; Hirahara et al. found all failures were intra-substance [20], Pennington et al. reported all failures were on the humeral side [3] whilst Denard et al. demonstrated the majority were on the humeral side (63.6%) but intra-substance 27.3% and glenoid sided failures (9.1%) were also present [19]. The AHD was measured on plain radiographs in all four studies and details are given in Table 3. Two studies demonstrated significant increase in AHD after SCR [3,20], Denard et al. and Burkhart et al. showed no change in AHD postoperatively [18,19].

All five fascia lata autograft studies reported on the radiological status of the graft [3,12,15–17]; Mihata et al. demonstrated 95.8% of grafts to be intact at 60 months follow-up [17], De Campos Azevedo et al. found 90.9% to be intact at 24 months [14], Lim et al. reported 71% were intact at 15 months [16] and Lee et al. demonstrated 63.9% intact at 24.8 months [15]. Three studies reported the location of the SCR failure; De Campos Azevedo et al. found 100% of failures were on the humeral side [14], Lee et al. that 84.6% were on the humeral side [15], whereas Lim et al. found 77.8% of failures were located on the glenoid side [16]. No incidence of intra-substance tears were reported in the reviewed studies. All five studies demonstrated increases in AHD after SCR surgery using fascia lata autograft as illustrated in Table 3 [3,12,15–17].

4. Discussion

The main finding of this systematic review was that all included studies reported a significant improvement in functional outcome scores after SCR. The mean ASES scores improved from 23.5–54.5 preoperatively to 73.7–92.9 postoperatively across the studies. Functional outcomes significantly improved after SCR regardless of graft used, the functional results after SCR with fascia lata

Table 2
Summary of case series.

Study	Population	Intervention (s)	Outcomes	Results
Burkhart et al. [18] $n = 10$	Age 69 ± 1.5 90% male Massive cuff tear Hamada grade < 4 Profound pseudoparalysis (< 45 aFE)	Dermal allograft (3 mm thickness) Subscapularis or infraspinatus repair in all LHB tenodesis 40%, LHB tenotomy 20% 6 weeks immobilisation, 10 weeks passive ROM and active from 16 weeks	Mean FU 10.9 months ROM–aFE, aER ASES SSV VAS pain Radiographic	aFE 27.1 (24–30) to 159 (130–187), $p < 0.001$ aER 24 (10–39) to 43 (27–58), $p = 0.002$ ASES 53 (39–64) to 89 (79–99), $p < 0.002$ SSV 36 (31–42) to 91 (86–97), $p < 0.001$ VAS pain 4.6 to 0.5 Graft in tact 70%, 30% partially intact AHI 7 (5–9) to 6 (4–8) Revision rate 0%
Denard et al. [19] $n = 59$	Age 62 ± 8.7 Male 66.1% Primary IRCT	Dermal allograft (1 to 3 mm) LHB tenodesis 42%, LHB tenotomy 15%, Limited acromioplasty 81%, Distal clavicle excision 5% Subscapularis repaired if able 6 weeks immobilisation, passive ROM until 4 months	Mean FU 17.7 months ASES SSV VAS pain ROM Radiographic	ASES 43.6 to 77.5 SSV 35 to 76.3 VAS pain 5.8 to 1.7 aFE 130 to 158, ER 36 to 45, IR L3 to L1 Complication 6.8–3.4% falls, 1.7% LHB pain and 1.7% infection Revision 18.6–11.9% RSA, 3.4% SCR revision, 1.7% infection, 1.7% biceps tenodesis AHI 6.6 to 6.7 mm MRI 45% complete healing
Hirahara et al. [20] $n = 9$	Age 61.3 (47–78) Male 67% Full thickness RCT with reduced AHD	Dermal allograft–thickness not stated Double row suture bridge repair Posterior margin convergence 100%, anterior margin convergence 33%	FU 32.4 months ASES VAS pain ROM Radiographic	ASES 41.8 to 86.5 ($p < 0.0002$) VAS pain 6.3 to 0.4 ($p < 0.0002$) AHD 4.5 to 7.7 ($p < 0.05$) MRI 80% grafts intact 11% revision rate to RSA
Pennington et al. [3] $n = 88$	Age 59.4 (27–79) Male 69% IRCT with no significant joint degeneration	Dermal allograft 3 mm Posterior margin and anterior margin convergence LHB tenotomy 100%, limited acromioplasty 100%, distal clavicle excision 26% Passive ROM for 4 weeks, active assisted until 8 weeks then strengthening	FU 16–28 ASES VAS pain ROM Radiographic	ASES 52 to 82 VAS pain 4 to 1.5 AFE 121 to 160, abduction 103 to 159 AHI 7.1 to 9.7 mm MRI 4.5% failure rate Revision rate 1.2%
De Campos Azevedo et al. [14] $n = 22$	Age 64.8 ± 8.6 32% male IRCT Primary or recurrent tears Hamada grade 1 or 2	Fascia lata autograft (thickness 5–8 mm) Subscapularis repair 32%, LHB tenotomy 50%, LHB absent 50%, anterior acromioplasty 73% Posterior margin convergence 64% 3 weeks active assisted ROM, avoid active resisted until 6 months	FU 24 months Constant score SST SSV ROM Radiographic	Constant 17.5 to 64.9 SST 2.1 to 8.6 SSV 33 to 70 aFE 74.8 to 143.8, Abduction 53.2 to 120.7, ER 13.2 to 35.6, IR 1.2 to 3.8 Partial capsular graft tear in 9.1% AHI 6.4 to 7.1 mm Revision rate not stated
Lee et al. [15] $n = 36$	Age 60.9 = –6.2 Male 69% Large to massive IRCT Failed non-operative treatment < 70 years	Fascia lata autograft (thickness not stated) Subscapularis repaired when able, concomitant procedures not stated Posterior margin convergence 67%	FU 24.8 months ASES Constant score VAS pain ROM Radiographic	ASES 50.3 to 84 Constant 56.3 to 82.8 36.1% retear rate Non retear group Higher proportion of intact posterior repair 87% vs 31% Larger post op AHI 8.9 vs 6 mm Revision rate not stated
Lim et al. [16] $n = 31$	Age 65.3 (44–85) Male 29% Large to massive cuff tear with medial retraction Hamada grades 1 & 2 IRCT	Fascia lata autograft folded in 2 layers (> 6 mm thickness) LHB tenotomy if present Acromioplasty 100% Abduction brace 6 weeks then passive ROM	FU 15 months ASES Constant score VAS pain ROM Radiographic	ASES 54.4 to 73.7 ($p < 0.001$) Constant score 51.7 to 63.7 ($p < 0.001$) VAS pain 6 to 2.5 ($p < 0.001$) AFE 133 to 146, ER 28 to 30 AHD 5.3 to 6.4 29% graft retear on humeral side—no significant difference in functional outcomes Revision rate not stated

Table 2 (*Continued*)

Study	Population	Intervention (s)	Outcomes	Results
Mihata et al. [17] *n* = 24	Age 65.1 (52–77) Male 52% IRCT Hamada grades 1–4	Fascia lata autograft–folded to make 6–8 mm thickness Acromioplasty 100%, LHB tenodesis 4%, Subscapularis repair 38% Posterior and anterior margin convergence	FU 34.1 (24–51) ASES JOA UCLA ROM Radiographic	ASES 23.5 to 92.9 JOA 48.3 to 92.6 UCLA 9.9 to 32.4 AHD 4.6 to 8.7 mm Graft failure 4.2% and posterior cuff tear in 12.5%
Mihata et al. [12] *n* = 88	Age 66.2 (43–80) IRCT Group A–No pseudoparalysis > 90 aFE *n* = 45 Group B–moderate pseudoparalysis, no drop arm sign *n* = 28 Group C–Severe pseudoparalysis, drop arm sign, *n* = 15	Fascia lata autograft (6–8 mm thickness) LHB tenodesis 8%, LHB tenotomy 1%, acromioplasty 100%, subscapularis 39% Anterior and posterior margin convergence Abduction brace 4 weeks, 4–8 weeks passive and active assisted, from 8 weeks strengthening	FU 60 (35–110) ASES	
JOA ROM Radiographic complication	Group A ASES 43.6 to 96.5 JOA 61.2 to 95.2 aFE 142.7 to 163.6 Group B ASES 29.2 to 92.2 JOA 46.6 to 90.6 aFE 54.3 to 146.8 Group C ASES 20.3 to 91.8 JOA 40.6 to 92.3 aFE 36.7 to 150 4.5% graft failure rate Complication rate 9% 3.4% stiffness 3.4% anchor pull out 2.3% infection			

aFE: active forward flexion; ROM: range of motion; aER: active external rotation; ASES: American Shoulder and Elbow Surgeons score; SSV: Subjective shoulder value; VAS: Visual Analogue Score; AHI: Acromiohumeral Interval; SST: Simple Shoulder Test; RSA: reverse shoulder arthroplasty; SCR: superior capsule reconstruction; IRCT: Irreparable rotator cuff tear; HO: heterotopic ossification; JOA: Japanese Orthopaedic Association; UCLA: University of California, Los Angeles.

Table 3
Radiological follow up of grafts.

Study	Follow up	Graft Type	MRI graft intact	Location of graft failure	Mean preoperative AH distance (mm)	Mean postoperative AH distance (mm)
Burkart et al. [18] *n* = 10	Mean 10.9 months	Dermal	Graft intact 70% Partially intact 30%	Details not provided	7 ± 1	6 ± 1
Denard et al. [19] *n* = 59	Mean 17.7 months	Dermal	Graft intact 45% Graft failure 55%	Humeral side 63.6% Intra-substance 27.3% Glenoid side 9.1%	6.6 ± 3	6.7 ± 3.0
Hirahara et al. [20] *n* = 9	Mean 32.4 months	Dermal	Graft intact 80% Graft failure 20%	Intra-substance 100%	4.5 ± 2.25	7.7 ± 2.08
Pennington et al. [3] *n* = 88	16–28 months	Dermal	MRI only performed if pain Graft failure 5.5%	Humeral side 100%	7.1	9.7
De Campos Azevedo et al. [14] *n* = 22	Mean 24 months	Fascia lata autograft	Graft intact 90.9% Graft failure 9.1%	Humeral side 100%	6.4 ± 3.3	7.1 ± 2.5
Lee et al. [15] *n* = 36	Mean 24.8 months	Fascia lata autograft	Graft intact 63.9% Graft failure 36.1%	Humeral side 84.6% Glenoid side 15.4%	5.0 ± 2.1	8.1 ± 2.0
Lim et al. [16] *n* = 31	Mean 15 months	Fascia lata autograft	Graft intact 71% Graft failure 29%	Glenoid side 77.8% Humeral side 22.2%	5.3 ± 2.2	6.4 ± 2.3
Mihata et al. [17] *n* = 24	Mean 34.1 months	Fascia lata autograft	Graft intact 95.8% Graft failure 4.2% Failure of posterior margin convergence 12.5%	Details not provided	4.6 ± 2.2	8.7 ± 2.6
Mihata et al. [12] *n* = 88	Mean 60 months	Fascia lata autograft	Graft intact 95.5% Graft failure 4.5%	Details not provided	4.5	9.3

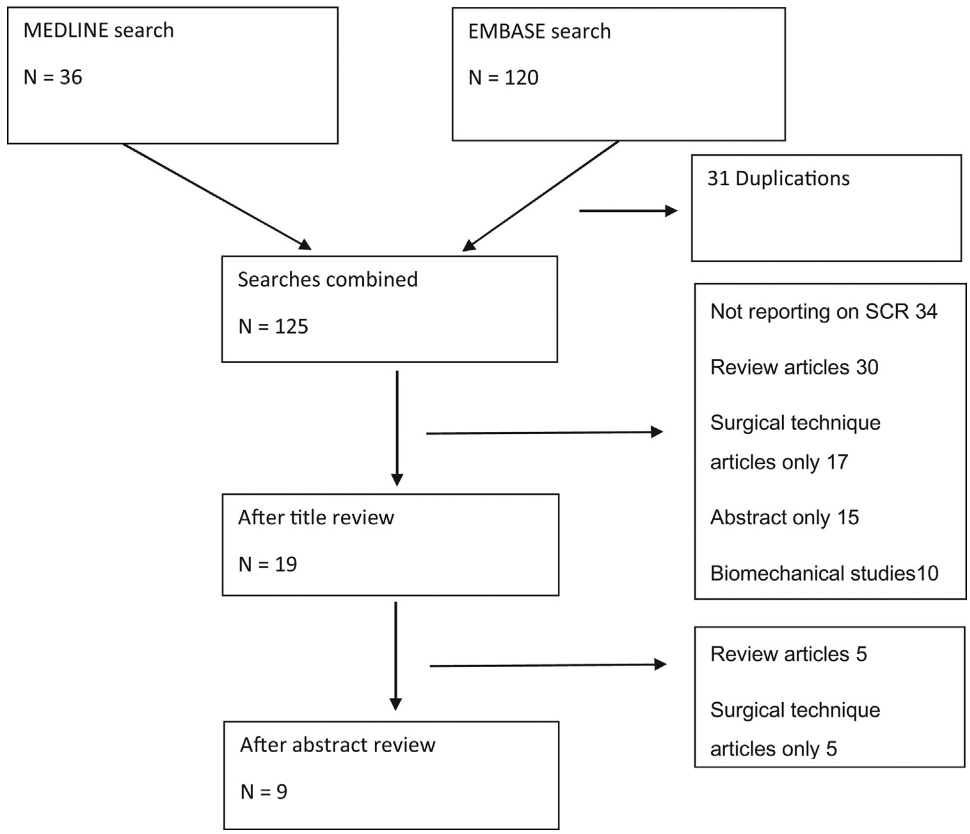

Fig. 1. Flow diagram of review process.

autograft and dermal allograft were comparable with final mean ASES scores ranging from 73.7 to 92.9 and 77.5 to 89 respectively [3,12,14,17–20]. In addition, the AHD significantly increased in two of four dermal allograft studies [3,20] and all five fascia lata autograft studies [12,14–17]. Mihata et al. reported the largest increase in ASES postoperatively, the authors used a 6–8-mm fascia lata autograft and also reported the largest increase in AHD postoperatively from mean 4.5 to 9.3 mm suggesting this may be an important factor in predicting functional outcome [17]. This finding is supported by Lee et al. who reported a significantly lower AHD immediately postoperatively in patients suffering a subsequent re-tear than those where grafts remained intact (1.6 mm vs 3.8 mm, $p = 0.02$) [15]. This lower AHD was measured immediately postoperatively, before re-tear occurred, suggesting that the risk of re-tear may relate to the thickness of the graft used, the graft tension and the position of the arm at the time of fixation.

Although all of the included studies reported significant improvements in functional outcomes there were no studies comparing the outcomes of SCR against those of patients undergoing other treatment options for IRCT (e.g. partial repair, balloon spacer arthroplasty, RSA). However, the functional improvements reported were broadly comparable to those previously described for these alternative surgical techniques. A review of the outcomes of partial rotator cuff repairs found a statistically significant improvement in functional outcome scores with mean ASES scores ranging from 41 to 46.6 preoperatively to mean of 73.8 to 80.1 postoperatively [21]. Despite this improvement in clinical outcomes, the reported overall rate of structural failures after partial repairs was 48.9% raising concerns about the long-term success of this technique [22]. A review of balloon spacer arthroplasty demonstrated significant improvement in functional scores with mean ASES scores ranging from 24.5 to 31.5 preoperatively to 72.5 to 85.7 postoperatively [23]. Similarly, a previous meta-analysis of the outcomes of RSA reported mean improvements in ASES from 33.3 preoperatively to 75.4 postoperatively [24]. It is important to highlight that although these scores appear broadly comparable, differences between studies preclude any strong conclusions. A particularly important difference to highlight is that the majority of studies included in the RSA meta-analysis had a mean age over 70 years, which was higher than the SCR studies included in the current review where the mean age ranged from 59 to 69 years. Although RSA maybe suitable in older patients where failure rates between 3.1 and 5.7% have been reported [25,26]. RSA should be used with caution in younger patient groups due to a high complication and failure rate [27–31]. Previous literature has reported failure rates of up to 25% in young patients with Serhson et al. reporting the highest rate of 25% at a mean of 34 months follow-up [27,29–31]. Similarly, Craig et al. reported a clear association between younger age and revision risk at all time points after elective shoulder replacement [32]. Clearly, there is an important need for comparative studies to better understand the role of each of these options in the management of IRCT. It is the opinion of the authors that this review demonstrates sufficient evidence of benefit of SCR to justify a randomised controlled trial investigating potential differences in outcomes between these procedures. Furthermore, it is important to highlight that there is a notable absence of cost effectiveness analyses in the literature and this will be important to address in future studies.

Although this review demonstrates that SCR performed with either autografts or allografts were associated with significant clinical improvements the lack of comparative studies also precluded strong conclusions about which graft type is the best option. However, it was identified that reported rates of radiological graft failures were higher after SCR performed with dermal allografts (20 to 55%) than fascia lata autografts (4.2 to 36.1%) [3,12,14–17,20] but the small overall numbers in the included studies limited the confidence in their ability to estimate the true incidence of graft rupture. Despite that, there remains a theoretical advantage with respect to autograft use, which may increase the likelihood of biological healing and produce less immunogenicity than allografts. Disadvantages of fascia lata autograft include donor-site morbidity, increased operative time and dependence on the quality of the harvested tissue. Only De Campos Azevedo et al. [14] reported on donor site morbidity, at 2 years 76.2% of patients reported ongoing local donor site changes. The most frequent complaints were the presence of pain 38.1%, numbness 38.1% and deformity 9.5%. Despite this high prevalence of donor site morbidity, 85.7% of patients stated that they would undergo the same surgery again [14]. Concerns over allograft use include disease transmission and delayed graft incorporation. In addition, literature comparing the use of autograft and allograft for other applications, e.g. anterior cruciate ligament reconstruction, have reported that the use of allografts may be associated with graft laxity and higher failure rates and this requires further investigation with respect to SCR [33–35]. However, previous results using allograft in the shoulder for either augmentation or bridging of massive rotator cuff tears have been positive. Snyder et al. demonstrated good integration, structural integrity and neovascularization of allografts when used for augmentation of rotator cuff repairs [36] and a recent review from Lewington et al. described allografts as a favorable option for bridging massive rotator cuff tears demonstrating functional improvement, imaging-supported graft survival, and lack of harvest complication risk [37].

SCR acts by providing a passive biological constraint to superior humeral head migration thus restoring a stable fulcrum [7,8]. This acts to restore the coronal force couple improving glenohumeral joint mechanics [38]. Biomechanical studies have demonstrated the superiority of superior capsule reconstruction compared to the use of a graft to bridge rotator cuff tears in obtaining superior stability [39]. In addition, biomechanical studies from Mihata et al. using fascia lata autografts have demonstrated the importance of graft thickness and SCR continuity with the remaining capsule to restoring function. In the studies reviewed, dermal allograft thickness ranged from 1 to 3 mm whereas the fascia lata autograft thickness ranged from 5 to 8 mm. Mihata et al. advocate the use of fascia lata autografts greater than 8 mm in thickness [40]. Hirahara et al. [20] reported improved function and reduction in pain if dermal allografts were over 3 mm in thickness but fail to report whether the findings were statistically significant.

Mihata et al. demonstrated the importance of side-to-side suturing of the graft to the margin of the rotator cuff in a biomechanical setting [10]. This finding has been reproduced in two included studies. Hirahara et al. reported a significant improvement in ASES scores in patients where anterior margin convergence was performed (93 vs 77, $p < 0.05$) [29]. Lee et al. [15] demonstrated the importance of the posterior margin convergence when using fascia lata autograft, reporting a lower incidence of graft failures in patients where posterior tissue integrity allowed posterior margin convergence to be performed (30.8% vs 87%, $p < 0.01$). Partial rotator cuff repairs similarly aim to preserve anterior and posterior tissue integrity and previous literature has demonstrated the ability of partial repairs of massive rotator cuff tears to improve both pain and functional outcomes scores. Shon et al. reported that at over 2 years follow-up ASES scores improved from 42 to 73.8 and pain scores from 5.1 to 3.1 ($p < 0.05$) after partial arthroscopic repair [41].

Shields et al. reported that previous rotator cuff repair was associated with lower ASES (76.5 vs 85.0, $p = 0.015$) and worse pain (2.0 vs 0.9, $p < 0.001$) after RSA than primary surgery [42]. Similarly, Farshad et al. reported that revision to RSA is associated with higher complication and failure rates when compared to primary RSA [43]. Therefore, the secondary surgery rate after SCR is clinically relevant as failed SCR may jeopardise results of future RSA. Four studies in this review reported secondary surgery rates ranging from 0% at mean 10.9 months [18] to 18.6% at mean 17.7 months follow-up [19]. Conversion to RSA was reported in three studies; 11.9% at 17.7 months [19], 11% at 32.4 months [20] and 1.2% at mean 22 months follow-up [3]. This relatively high revision rate is unsurprising given the challenging cohort of patients being managed. Alternative surgical interventions for IRCTs have had similarly high failure rates; balloon spacer arthroplasty 3 to 8.3% [44–48], reverse shoulder arthroplasty 17% [49] and partial cuff repair 4 to 8% [50,51]. The short term follow-up reported in the majority of the studies included in this review raises concern that the revision rate would be higher if this was extended to the mid- or long-term. Therefore, further studies reporting long-term results and the sequelae of failed SCR are required.

The radiographic failure of SCR grafts in the studies reviewed ranged from 4.2 to 55% with variable follow-up as illustrated in Table 3. Previous studies have shown similar graft failure rates in the setting of bridging reconstruction of large to massive rotator cuff tears where failure ranged from 10 to 40% [37]. The location of graft failure in this review varied between the studies although the majority were humeral sided failures with intra-substance

Table 4

Methodological items for non-randomised studies (MINORS) Scores for included studies.

	Pennington [3]	De Campo [14]	Mihata [17]	Lee [15]	Lim [16]	Mihata [12]	Burkhart [18]	Denard [19]	Hirahara [20]
A clearly stated aim	2	2	2	2	2	2	2	2	1
Inclusion of consecutive patients	2	2	2	1	1	2	1	1	1
Endpoints appropriate to the aim of the study	2	2	2	2	2	2	2	2	2
Unbiased assessment of the study endpoint	1	0	1	2	2	1	1	0	0
Follow-up period appropriate to the aim of the study	2	2	2	2	2	2	1	1	2
Loss to follow up less than 5%	2	2	2	2	2	2	2	0	1
Prospective calculation of the study size	0	0	0	0	0	0	0	0	0
Additional criteria in the case of comparative study	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
An adequate control group	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Contemporary groups	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Baseline equivalence of groups	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Adequate statistical analyses	2	2	2	2	2	2	2	2	1
Total score	13/16	12/16	13/16	13/16	13/16	13/16	11/16	8/16	8/16

MINOR scores: 0 (not reported), 1 (reported but inadequate) and 2 (reported and adequate).

tears only seen in the dermal allograft group as illustrated in Table 3. Despite this high failure rate, most patients still experienced improved functional outcome scores with two studies reporting no significant differences in functional scores between the re-tear and graft intact groups [15,16]. This improvement in functional scores despite failure has previously been reported after rotator cuff repairs [52,53]. However, one included study did report a significantly higher improvement in function where the graft remained intact; Denard et al. [19] demonstrated that 100% of patients with healed grafts had a successful outcome compared to 45.5% when the graft did not heal ($p = 0.009$). Alternative studies from the literature reporting on rotator cuff repairs have shown important differences in clinical outcomes between patients with healed and non-healed rotator cuff repairs [54]. Therefore, the importance of graft integrity after SCR remains unknown and further studies are needed to clarify this and identify other important prognostic factors.

Appraisal of the included studies according to the MINORS criteria showed a variation in the quality of studies reviewed, see Table 4. Weaknesses common to most studies included low study numbers, the lack of a comparative group and heterogeneity of included patients. Variation also existed in surgical technique including graft fixation, graft thickness and routine anterior or posterior marginal convergence. Concomitant procedures were performed in all studies but the number and type of these varied as shown in Table 2. Previous studies have reported that isolated debridement and biceps tenotomy for massive cuff tears can be successful at least in the short term [55–58]. Therefore, any benefit reported in the included studies may be due at least in part to these concomitant procedures such acromioplasty and LHB tenotomy. Future study design must consider the effect of these procedures. However, the review has confirmed that SCR provides an alternative treatment option in this challenging cohort of patients but further studies reporting on the long-term outcomes of the technique and comparing it against the alternatives are required.

5. Conclusion

This review demonstrates that SCR is a useful treatment modality for patients with irreparable rotator cuff tears. SCR was associated with significantly improved functional outcome scores in all studies. All studies reported a preserved or increased mean AHD. The radiological graft failure rate ranged from 4.2 to 55% and the short duration of follow-up in most studies means that this remains an important concern that requires longer-term evaluation.

Disclosure of interest

A. Saithna and M. Daggett are consultants with Arthrex. The other authors declare that they have no competing interest.

Funding sources

No funding was received during the production of this manuscript.

Author contribution

R. Jordan and N. Sharma performed the literature searches, appraised the articles and produced the manuscript.

M. Daggett and A. Saithna were responsible for the topic of the review, overseeing the searches and appraisal of the literature and editing the final manuscript.

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