Original Article

Similar Value Demonstrated in the Short-Term Outcomes of Superior Capsular Reconstruction and Reverse Shoulder Arthroplasty for Massive Rotator Cuff Tears

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Purpose: The purposes of this study were to investigate the difference in value (benefit to cost ratio) of dermal allograft superior capsular reconstruction (SCR) versus reverse total shoulder arthroplasty (rTSA) for the treatment of massive rotator cuff tears (MRCTs) without arthritis; to compare the patient populations selected for the operations and report pre- and postoperative functional data; and to understand other characteristics of the 2 operations, including operating time, use of institutional resources, and complications. **Methods:** A retrospective, single-institution analysis during the study period 2014-2019 with MRCT treated with SCR or rTSA by 2 surgeons with complete institutional cost data and minimum 1-year clinical follow-up with American Shoulder and Elbow Surgeons (ASES) score. Value was defined as ΔASES/(total direct costs/$10,000). **Results:** Thirty patients underwent rTSA and 126 patients SCR during the study period with significant differences noted in patient demographics and tear characteristics between the groups (patients who underwent rTSA were older, less male, had more pseudoparalysis, had greater Hamada and Goutallier scores, and had more proximal humeral migration). Value was 25 and 29 (ΔASES/$10,000) for rTSA and SCR, respectively ($P = .7$). The total costs of rTSA and SCR were $16,337 and $12,763, respectively ($P = .7$). Both groups experienced substantial improvements in ASES scores: 42 for rTSA vs 37 for SCR ($P = .6$). The operative time for SCR was much longer (204 vs 108 minutes, $P < .001$) but complication rate lower (3% vs 13%, $P = .02$) versus rTSA. **Conclusions:** In a single institutional analysis of the treatment of MRCT without arthritis, rTSA and SCR demonstrated similar value; however, the value calculation is highly dependent on institution specific variables and duration of follow-up. The operating surgeons demonstrated different indications in selecting patients for each operation. rTSA had an advantage over SCR in shorter operative time, whereas SCR demonstrated a lower complication rate. Both SCR and rTSA are demonstrated to be effective treatments for MRCT at short-term follow-up. **Level of Evidence:** III, retrospective comparative study.

One of the many challenges in treating massive rotator cuff tears (MRCTs) is that similar improvements in patient outcomes can be achieved with dissimilar procedures that vary widely in focus, technical complexity, and resource use. This complicates the decision-making process for surgeons both at the

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individual patient level and at the health care system level. Surgeons must always try to make the best diagnostic and therapeutic decisions for the individual patient but are also increasingly tasked with demonstrating that their operative procedures are quantitatively beneficial and demonstrate high value (benefit to cost).

In treating MRCT, reverse total shoulder arthroplasty (rTSA) has exhibited good results but is costly and can be associated with substantial risks.[1] Recently, superior capsular reconstruction (SCR) has emerged as an alternative to rTSA for certain irreparable MRCTs.[2,3] SCR has been quickly adopted[2]; however, it is technically demanding, and few reports exist detailing the resources used to achieve the benefits of this operation. SCR has the added benefit of preserving native joint anatomy, allowing the option for future revision surgeries or ultimately conversion to an arthroplasty construct; however, the long-term outcomes for the procedure are still unknown. Currently, there exists minimal information to allow a comparison of the value of SCR and rTSA as alternative operations for MRCT.

The purposes of this study were to investigate the difference in value (benefit-to-cost ratio) of dermal allograft SCR versus rTSA for the treatment of MRCT without arthritis; to compare the patient populations selected for the operations and report pre- and postoperative functional data; and to understand other characteristics of the 2 operations, including operating time, use of institutional resources, and complications. We hypothesized that both SCR and rTSA would be effective treatments for MRCTs without arthritis, with good outcomes, operative times, and complication rates.

Methods

Study Design

A retrospective analysis was performed on patients with MRCTs without glenohumeral arthritis surgically treated at a single hospital by 2 surgeons between 2014 and 2019. The study period was chosen to include the entire period that the surgeons treated MRCT with either SCR or rTSA until 1 year before study initiation. Institutional review board approval was obtained before commencing the study An Institutional Review Board exemption was obtained prior to study commencement due to its retrospective nature. Patients treated with SCR by 1 surgeon (S.S.B.) were compared with patients treated with rTSA by another surgeon (R.U.H.)

Inclusion and Exclusion Criteria

Inclusion criteria were patients with MRCT (2 complete tendons torn or tear size >5 cm on preoperative magnetic resonance imaging or intraoperatively) and minimal evidence of glenohumeral arthritis (Hamada $\leq$3). Using these criteria, the authors sought to include all patients who would have been potential candidates for either operation in both the operating surgeons' practices but were selected for SCR or rTSA based on other patient and imaging factors aside from tear size and the presence of glenohumeral arthritis. Patients having a SCR as an augment to complete rotator cuff repair were excluded from analysis. Patients who underwent tendon transfer were excluded. Patients were excluded for surgery at other practice locations (e.g., ambulatory surgery center), incomplete cost data, lacking at least 12-months' follow-up, and lacking pre- and postoperative American Shoulder and Elbow Society (ASES) scores. Since the authors have previously reported similar outcomes between 1- and 2-year follow-up for SCR,[4,5] a shorter follow-up period was chosen to maximize the number of eligible patients. Of note, some patient (SCR) clinical outcomes have been previously published by the authors.[4] The individual surgeons for each group analyzed the plain radiographs (acromiohumeral interval, in millimeters),[6] Hamada stage[7]) and magnetic resonance imaging scans (Goutallier grade[8]) for each patient. Preoperative pseudoparalysis was defined as the condition of active shoulder forward elevation less than or equal to 90° with full passive forward elevation.[9]

Cost Calculation and Value Analysis

There are many different ways in which health care costs have been analyzed in the literature (e.g., cost-effectiveness, cost-utility, cost-benefit, cost-minimization analysis).[10] In this study, the main outcome variable was chosen as value, as defined previously, since this can provide a framework for comparing the interprocedural efficacy of medical interventions.[11,12] The total short-term cost of MRCT operations can be estimated by the direct hospital costs during the index operation.[13,14] Direct hospital costs are defined here to represent the dollar amount for the surgical and medical overhead that would encompass the entire episode of care for a given procedure. Direct hospital cost data reflect all items that are billable and nonbillable and may differ from the hospital charge data and hospital reimbursement. Direct hospital costs (total cost) of each procedure were provided directly by the institution. Cost data were further categorized as direct surgical costs (e.g., operating room costs and implants) and nonsurgical costs (e.g., other supplies and facility fees). Indirect costs such as utilities and administrative fees were not able to be calculated by the institution for this analysis. Other costs such as that of preoperative imaging and surgeon and anesthesia fees were assumed to be roughly equal between the operations, were not institutional costs, and were not included in the analysis. Cost and functional data were used to calculate the value of each patient's procedure. Value was defined as a ratio of health outcome to cost.[12] This has previously been measured in the shoulder as improvement in the

Table 1. Demographic Data for Patients Treated With rTSA and SCR for MRCT

Characteristic	Overall N = 156*	rTSA N = 30*	SCR N = 126*	*P* Value†
Sex				.008
Female	47 (30%)	15 (50%)	32 (25%)	
Male	109 (70%)	15 (50%)	94 (75%)	
Age at surgery, y	68 (64, 74)	72 (65, 79)	68 (61, 72)	.005
Dominant arm	111 (76%)	18 (90%)	93 (74%)	.12
Unknown	10	10	0	
Affected side				.4
Both	1 (0.6%)	0 (0%)	1 (0.8%)	
Left	53 (34%)	7 (23%)	46 (37%)	
Right	102 (65%)	23 (77%)	79 (63%)	
Number of previous repairs				.002
0	87 (56%)	9 (30%)	78 (62%)	
1	48 (31%)	11 (37%)	37 (29%)	
2	14 (9.0%)	6 (20%)	8 (6.3%)	
3	4 (2.6%)	2 (6.7%)	2 (1.6%)	
4	3 (1.9%)	2 (6.7%)	1 (0.8%)	
Surgical encounter type				<.001
Inpatient	39 (25%)	28 (93%)	11 (8.7%)	
Outpatient	89 (57%)	1 (3.3%)	88 (70%)	
Short stay/ observation	28 (18%)	1 (3.3%)	27 (21%)	

MRCT, massive rotator cuff tear; RTSA, reverse shoulder arthroplasty; SCR, superior capsular reconstruction.
*n (%); median (interquartile range).
†Pearson χ^2 test; Wilcoxon rank sum test; Fisher exact test.

ASES score divided by scaled total cost,[15-18] since ASES scores have a comparably high validity, reliability, and responsiveness as a good estimate of health utility.[3,11] This study reports value defined by ΔASES/(total direct costs/$10,000).[15] Both surgeons routinely obtained prospective, patient self-reported preoperative and 12-month postoperative ASES scores.

Complications, Reoperation, and Revision

Complications were defined as intraoperative or postoperative events that were likely to have a negative impact on the patient's final outcome including fractures, graft tears or failure, infection, dislocation, nerve palsy, aseptic loosening of components, or problems arising from hardware placement or failure. Reoperation was defined as an intervention requiring any return to the operating room for any reason relating to the shoulder while not altering or replacing the graft or hardware. Revision operation was defined as a procedure with total or partial exchange or removal of graft or hardware components.[19]

Statistical Analysis

The statistical analysis was performed by an independent data scientist (J.M.P.) in R[20] using the RStudio[21] integrated development environment. The *tidyverse*[22] and *janitor*[23] packages were used to tidy and transform data before analysis. Continuous variables are reported as the median and interquartile range. Comparisons between preoperative and postoperative continuous variables, including age, ASES score, operative time, and cost variables, were evaluated using Wilcoxon signed-rank tests, with a nominal α set at 0.05. Categorical demographic variables and ordinal imaging variables were reported as proportions of the group cohort and were evaluated using either the Fisher exact test or Pearson's χ^2 test. Summary statistics were calculated using the *gtsummary* package.[24]

Results

The records of 216 patients were initially screened as eligible for the study based on review of the practice electronic medical record during the study period for Current Procedural Terminology codes and corresponding diagnosis of the surgeon. Fifty-four patients were excluded as having an over-the-top repair as an augment to the SCR. Five patients with rTSA were excluded for radiographic evidence of severe arthritic change (Hamada 4-5). One patient who underwent tendon transfer surgery was excluded. One-hundred fifty-six patients had at least 1-year follow-up and were included in the final analysis, which included 30 rTSAs and 126 SCRs. None of these 156 patients were excluded from the value analysis; however, several patients lacked complete imaging data, as noted.

Preoperative imaging data are presented in Table 2, with significant differences noted between the rTSA and SCR groups. Patients undergoing rTSA had more proximal humeral migration than patients undergoing SCR (acromial humeral interval 5 vs 7 mm, $P < .001$). Patients undergoing rTSA had greater Hamada grades (70% vs 29% grades 2-3, $P < .001$) and levels of Goutallier 3-4 fatty infiltration of subscapularis (59% vs 15%, $P < .001$) and infraspinatus (72% vs 39%, $P = .02$). In addition, patients undergoing rTSA had worse baseline ASES scores than patients undergoing SCR (33 vs 48, $P = .002$) (Table 3). Twenty-seven (21%) patients undergoing SCR had preoperative pseudoparalysis versus 15 (50%) undergoing rTSA ($P = .03$).

ASES scores, operating room time, cost, and value are shown in Table 3. ASES scores differed preoperatively, as noted, and at prospective 12-month follow-up for rTSA and SCR: 80 (63, 90) versus 88 (80, 95), $P = .005$. However, there was no difference in the magnitude of improvement in ASES scores between groups (42 vs 37; $P = .6$). Facility usage differed significantly, with rTSA using less operating room time: 108 (90, 122) versus 204 (179, 221) minutes ($P < .001$, Table 3), with mean 7 suture anchors used for SCR. rTSA procedures had a significantly lower surgical costs compared with SCR:

Table 2. Preoperative Imaging Data for MRCT Treated With RTSA and SCR

Characteristic	Overall N = 156*	rTSA N = 30*	SCR N = 126*	P Value†
Hamada grade				
1	89 (61%)	9 (30%)	80 (69%)	<.001
2	26 (18%)	10 (33%)	16 (14%)	
3	28 (19%)	11 (37%)	17 (15%)	
4	3 (2.1%)	0 (0%)	3 (2.6%)	
Unknown	10	0	10	
AHI, mm	6.30 (4.30, 8.07)	5.00 (2.25, 6.00)	6.95 (5.10, 8.50)	<.001
Unknown	10	0	10	
Goutallier grade				
Supraspinatus				
0	6 (4.5%)	0 (0%)	6 (5.8%)	.7
1	21 (16%)	5 (17%)	16 (15%)	
2	42 (32%)	9 (31%)	33 (32%)	
3	33 (25%)	6 (21%)	27 (26%)	
4	31 (23%)	9 (31%)	22 (21%)	
Unknown	23	1	22	
Infraspinatus				
0	7 (5.3%)	0 (0%)	7 (6.8%)	.022
1	28 (21%)	2 (6.9%)	26 (25%)	
2	35 (27%)	6 (21%)	29 (28%)	
3	29 (22%)	9 (31%)	20 (19%)	
4	33 (25%)	12 (41%)	21 (20%)	
Unknown	24	1	23	
Subscapularis				
0	27 (21%)	1 (3.4%)	26 (25%)	<.001
1	49 (37%)	3 (10%)	46 (45%)	
2	23 (18%)	8 (28%)	15 (15%)	
3	15 (11%)	6 (21%)	9 (8.8%)	
4	17 (13%)	11 (38%)	6 (5.9%)	
Unknown	25	1	24	

AHI, acromial humeral interval; MRCT, massive rotator cuff tear; RTSA, reverse shoulder arthroplasty; SCR, superior capsular reconstruction.
*n (%); median (interquartile range).
†Fisher exact test; Wilcoxon rank sum test.

$8,220 ($8,145, $8648) versus $10,561 ($10,220, $10,885), respectively ($P < .001$). Despite this, direct hospital costs (total cost) averaged $16,337 ($10,908, $19,842) for rTSA and $12,763 ($10,835, $14,582) for SCR ($P = .06$). Value of the procedures based on total cost was calculated to be 25 (11, 41) and 29 (13, 41) ΔASES/$10,000 for rTSA and SCR respectively ($P = .7$).

Four of 126 (3%) patients who underwent SCR experienced complications, including one reoperation of a failed biceps tenodesis construct, one revision of a torn SCR graft, one revision of a traumatically failed SCR to rTSA, and a postoperative stroke requiring hospitalization. Four of 30 (13%, $P = .02$) patients who underwent rTSA experienced complications, including 2 acromial fractures, 1 periprosthetic fracture treated nonoperatively, and 1 unstable reverse requiring revision.

Discussion

This study conducted an analysis using institutional cost data representing the direct medical and surgical overhead for SCR and rTSA procedures with patient-reported outcomes to determine the value of each procedure in the short-term setting. Since the procedures were either joint-preserving or prosthetic arthroplasty, the populations were expected to differ in preoperative characteristics; however, this analysis assumed these factors would have little influence on the cost of the procedure. Costs would more be driven by the price and quantity of intraoperative hardware (suture anchors, graft, arthroplasty components) and operative duration. The findings of this study support the study hypothesis of no difference in value between 2 operations, SCR and rTSA, for the treatment of MRCTs without arthritis. Interestingly, basic parity was demonstrated for these very different procedures in both the numerator (clinical benefit) and denominator (cost) of the value equation. Therefore, it seems reasonable to conclude that from a high-level, economical viewpoint, SCR and rTSA represent equivalent choices in the treatment of MRCT.

There were expected demographic differences between the groups, as seen in Table 1. The patients who underwent rTSA were older (72 vs 68 years, $P = .005$)

Table 3. Outcomes Cost and Value Data for MRCT Treated With SCR and RTSA

Characteristic	Overall N = 156*	rTSA N = 30*	SCR N = 126*	*P* Value†
Preoperative ASES score	43 (32, 58)	33 (24, 47)	48 (35, 58)	.002
1-year ASES score	87 (77, 93)	80 (63, 90)	88 (80, 95)	.005
Change in ASES score	38 (22, 50)	42 (20, 57)	37 (22, 50)	.6
Operative time, min	192 (163, 215)	108 (90, 122)	204 (179, 221)	<.001
Direct hospital costs, USD	12,816 (10,873, 15,390)	16,337 (10,907, 19,842)	12,763 (10,835, 14,582)	.063
Surgical costs, USD	10,441 (9,941, 10,829)	8,220 (8,145, 8,648)	10,561 (10,220, 10,885)	<.001
Value‡	28 (13, 41)	25 (11, 41)	29 (13, 41)	.7

AHI, acromial humeral interval; ASES, American Shoulder and Elbow Surgeons; MRCT, massive rotator cuff tear; RTSA, reverse shoulder arthroplasty; SCR, superior capsular reconstruction.

*Median (interquartile range).

†Wilcoxon rank sum test.

‡Value presented as ΔASES/$10,000 cost.

and less male (50% vs 75%, $P = .016$) than patients who underwent SCR. Patients who underwent SCR had significantly lower number of previous rotator cuff repairs: 62% (SCR) vs 30% (rTSA) had no previous repair ($P = .002$). Hospital encounter type also differed significantly between the 2 groups: 93% of rTSA procedures were categorized for inpatient stay versus 9% of SCR operations. Although not admitted as inpatients, patients who underwent SCR were routinely observed overnight for monitoring secondary to the length of the procedure.

In the current study, an approximately 25% difference in total costs (direct hospital costs) favoring SCR was found; however, it is interesting that the direct surgical costs favored rTSA by approximately 25%. The latter difference likely resulted from capped rTSA implant pricing at the institution plus a combination of longer surgical time for SCR with the use of a large number of implants (average of 7 suture anchors and an acellular dermal graft). The relative value of SCR versus rTSA could be increased by efforts to decrease operating room time and implant costs for this procedure. Implant price has been reported as a major contributor of the overall cost of rTSA and a significant driver of cost-effectiveness.[25] Thus, in high-volume institutions, negotiated implant prices can drastically alter cost and therefore the value calculation. Despite the small advantage in direct surgical costs, the total cost to the institution for rTSA was still greater compared with SCR, likely through either nonoperative facility costs from more inpatient hospital admissions or the greater reoperation rate (3% vs 0.8%) in the former group. As rTSA is increasingly performed in the hospital outpatient and ambulatory surgical center environment, the value of rTSA for MRCT through lower nonsurgical costs should continue to improve.[26]

The current study was initiated primarily to investigate the institutional costs and benefits for these competing MRCT operations. A drawback of this approach is that the demographics and disease characteristics of the patient groups were not equivalent. Alternatively, a benefit of the study design is that it provides a retrospective view of the factors that were associated with the authors' use of rTSA during the study period. These included patient factors (older age and equal sex distribution), tear factors (more previous repairs, proximal humeral migration, and cuff muscle fatty degeneration), and clinical factors (preoperative pseudoparalysis). Patients treated with rTSA were worse preoperatively by self-reported ASES score. The authors have previously written about their indications for prosthetic reconstruction (rTSA) versus joint-preservation surgery for MRCT without arthritis, and these results generally support that the above factors were important in the surgical decision making used during the current study period.[2]

Pappou et al.[15] first proposed a metric for describing the value of shoulder arthroplasty using ASES scores and total direct hospital costs (ΔASES/$10,000). A subsequent study showed that through lower implant costs, anatomic TSA had nearly double the value of rTSA (26 vs 15 ΔASES/$10,000) for matched patients with cuff-intact shoulder arthritis.[17] Using this methodology, the value of rTSA for MRCT previously has been reported as approximately 18 ΔASES/$10,000.[16] The current study showed a greater calculated value (25 ΔASES/$10,000) compared with that previously reported; however, this difference likely reflects that in the current study indirect costs were not available from the hospital. The direct costs reported in the current study differ minimally from those reported previously by Hartzler et al.[16] ($16,337 vs $18,367). Thus, it is unlikely that the overall value of rTSA for MRCT has appreciably changed since 2015. Several other recent studies have reported value of rTSA; however, those study methodologies that do not lend well to direct comparison with the results of the current study.[18,27]

A study result warranting discussion is the long operating room time reported for SCR, especially considering that these cases were performed by an experienced shoulder arthroscopist (S.S.B.). The longer operating room time reflects the technical complexity of SCR, which in our practices consist of multiple complex subprocedures including SCR proper, arthroscopic subscapularis repair, biceps tenodesis, infraspinatus partial repair, interval slides, etc.[4] This technical complexity potentially represents a barrier to reliably achieving the patient-reported improvements and graft healing rates published by those authors who have reported most on SCR.[28,29] On an individual case basis, the complexity of SCR might have negligible effect on institutional resources; however, over time SCR might represent a significant opportunity cost (e.g., non-reimbursable operating room time and personnel-hours) versus other operations for MRCT. Furthermore, SCR has a reported clinical and radiographic failure rate between 3.4% and 36.1% with up to 10.4% requiring a revision to rTSA.[30] Although SCR has shown promising short-term outcomes, the long-term outcomes are still unknown and any revision or reoperation that may occur may significantly affect the long-term value of the procedure.

As mentioned previously, the greater reoperation rate for rTSA (3%) versus SCR (0.8%) might have contributed to the difference in total costs (direct hospital costs) seen in the study, since reoperation costs were accounted for in the current analysis. The long-term impact of the cost of reoperation or revision for these operations is unknown, primarily since the long-term survivorship of SCR is unknown. Although the complication and reoperation rate for SCR is low in this series, there is a high degree of variability between published literature for SCR.[31] From a clinical point of view, the joint-preserving nature of SCR offers a greater range of later surgical options compared with rTSA in the event of failure.

Limitations

As in any investigation, the authors made certain assumptions during the study design. As has been done previously, the current study estimated that direct hospital costs accrued during the hospitalization are representative of the total cost for each procedure.[13] Several cost factors that are not easy to quantify or for which institutional data were lacking were assumed to be equal and were not accounted for in the analysis. This may have led to some degree of underreporting of costs in the current study; however, the study results are generally in line with cost data already reported in the literature.[1,16,32] This study presents the direct overhead costs to a hospital for the 2 procedures; however, the analysis was limited by the data available. With much more robust cost data, a comparison between the direct hospital costs, total charges, and total reimbursement would better clarify the economic differences between the 2 procedures, as has been published by Polisetty et al.[33] However, there exist many problems in reporting and interpreting value. The lack of standardized reporting, cost calculation, and institutional variability in care make objective comparisons difficult.[3,25,34,35] Numerous factors including practice environment (inpatient vs outpatient), geographic region, negotiated supplier prices, and institutional volume can cause large variations in the cost data included in the value equation.

This study is not without limitations. The study is inherently limited by its retrospective nature. Patients treated with SCR versus rTSA were neither randomized nor uniform. Although the study was limited to a single institution to control for certain variables, each procedure was performed a different surgeon, which limits generalizability. As mentioned, the study data are limited to 2 surgeons, and the analysis would change if the factors such as operating time or complication rate were different between surgeons for these operations. Further limitations include the short-term nature of clinical follow-up in calculating value.

Conclusions

In a single institutional analysis of the treatment of MRCT without arthritis, rTSA and SCR demonstrated similar value; however, the value calculation is highly dependent on institution-specific variables and duration of follow-up. The operating surgeons demonstrated different indications in selecting patients for each operation. RTSA had an advantage over SCR in shorter operative time, whereas SCR demonstrated a lower complication rate. Both SCR and RTSA are demonstrated to be effective treatments for MRCT at short-term follow-up.

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