Journal of Shoulder and Elbow Arthroplasty
Volume 3: 1–9

DOI: 10.1177/2471549219831527
journals.sagepub.com/home/sea

Clinical Predictors for Optimal Forward Elevation in Primary Reverse Total Shoulder Arthroplasty

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Abstract

Background: Few studies in the literature analyze clinical factors associated with superoptimal and suboptimal forward elevation in primary reverse total shoulder arthroplasty (RTSA). We investigate the functional outcome stratified by shoulder elevation 12 months after primary RTSA and its correlation with selected clinical patient factors.

Methods: We analyzed prospectively collected data within a comprehensive surgical database on patients who had undergone primary RTSA between June 2004 and June 2013. Two hundred eighty-six shoulders were stratified into 2 groups: group I for shoulders that had achieved at least 145° of active forward elevation 12 months postoperatively (90th percentile of active forward elevation, 29 shoulders) and group II for shoulders that never achieved at least 90° of active forward elevation 12 months postoperatively (10th percentile of active forward elevation, 28 shoulders). Statistical analysis associated independent clinical variables with postoperative motion using univariate analysis followed by logistic regression.

Results: Active shoulder elevation of at least 90° was achieved 12 months postoperatively in 259 subjects (90%). Upon comparison with group II ($<$90° elevation), subjects in group I ($\geq$145° elevation) were found to have improved postoperative active elevation and relatively younger age, lower American Society of Anesthesiologists score, increased preoperative active elevation, increased shoulder strength, increased passive elevation, decreased elevation lag, increased active and passive external rotation, and improved validated outcome scores. When assessing significant preoperative variables, the only independent predictor of improved postoperative forward elevation was preoperative active forward elevation.

Conclusion: These findings illuminate significant factors in the ability to achieve functional active shoulder elevation after primary RTSA. They may help surgeons appropriately counsel patients about anticipated functional prognosis following primary RTSA.

Keywords

Active shoulder elevation, elevation lag, functional outcomes, functional prognosis, passive elevation, reverse total shoulder arthroplasty

Date received: 8 January 2018; revised: received 17 December 2018; accepted: 24 January 2019

Introduction

Reverse total shoulder arthroplasty (RTSA) is an effective procedure for treating pain and functional disability in patients with shoulder pathology associated with rotator cuff compromise. Such pathologic conditions include rotator cuff tear arthropathy, proximal humerus fractures, massive rotator cuff tears, inflammatory arthropathy, tumors, and failed primary shoulder

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arthroplasty, among others.[1–4] Outcome studies of RTSA have demonstrated achievements of maximal postoperative active shoulder elevation of 105° to 138° on average.[5–10] A small three-dimensional (3D) motion analysis study demonstrated average improvements in glenohumeral active elevation of 43° (from 66° preoperatively to 109° postoperatively).[11] With this improvement in active shoulder range of motion, the majority of patients treated with RTSA are able to improve their function and perform activities of daily living.[12]

Several studies have investigated biomechanical predictors for success in optimizing functional capacity following RTSA.[11,13,14] The RTSA offers its biomechanical advantage in the absence of a functional rotator cuff through altering the joint constraint and increasing the deltoid lever arm and muscle tension.[11,13,14] Given the biomechanical properties of RTSA allowing improvement in shoulder function while maintaining joint stability, there has been widespread interest in investigating the biomechanical predictors for success.[15] This being said, there has been a paucity of information in the available literature focusing on clinical predictors for success after RTSA.

Some studies have evaluated preoperative risk factors associated with complications after RTSA. One retrospective study by Johnson et al. demonstrated an association between elevated American Society of Anesthesiologists (ASA) score and surgical complications, such as prosthetic failure.[16] Moreover, obesity has been implicated as a risk factor for the development of complications after RTSA.[17] This information is useful in gauging risk factors for postoperative complications; it does not, however, postoperative function. Some studies have suggested preoperative and intraoperative motion, as well as male gender and preoperative diagnosis, as important factors in predicting postoperative function.[18] This being said, research into this area is limited. The purpose of our study is to test the null hypothesis that these clinical patient factors, among others, do not correlate with active shoulder forward elevation after RTSA.

Materials and Methods

This study was approved by Western Institutional Review Board (study number 1112376). A retrospective review was conducted using a prospective collected database on patients who underwent primary RTSA at the University of Florida Health System hospitals between June 2004 and June 2013. Inclusion criteria were patients who underwent primary RTSA for the diagnosis of rotator cuff tear arthropathy, osteoarthritis with rotator cuff deficiency, irreparable rotator cuff tear, or proximal humerus fracture, with a minimum of 12 months of follow-up. All patients, with the exception of those treated in the acute setting for proximal humerus fracture, underwent a trial of conservative treatment prior to surgical intervention.

Our initial query yielded 325 patients (365 shoulders) performed during the inclusion time period. Fifty-two subjects were excluded for less than 12 months of follow-up. Seventeen were excluded due to diagnoses other than those listed in the inclusion criteria. These included posttraumatic arthritis (10), proximal humerus fracture malunion or nonunion (6), rheumatoid arthritis (6), osteonecrosis of the humeral head (3), pigmented villonodular synovitis (1), and chronic shoulder dislocation (1). No revision arthroplasty cases were included in the series. The final study population included 272 patients (286 shoulders), comprised of 127 males (55.6%) and 159 females (44.4%). The mean age of the patients at the time of surgery was 71.5 years (range, 41–93 years).

Initial analysis of our data revealed that 28 of the 286 shoulders (10%) did not achieve more than 90° of active elevation 12 months postoperatively. A cohort of shoulders comprising the 90th percentile of active elevation was established for comparison. Incidentally, this group contained 29 shoulders (10%) that achieved at least 145° of active elevation 12 months postoperatively. These 2 cohorts were designated as group I for the 90th percentile of active elevation and group II for the 10th percentile of active elevation.

The RTSA procedures were performed by 1 of the 3 surgeons, including 2 authors of this study. All cases were performed through a deltopectoral approach. Five different RTSA prosthesis types were used, including 219 Equinoxe (Exactech, Gainesville, FL), 36 Encore (Don Joy Orthopaedics, Vista, CA), 23 Aequalis (Tornier, Bloomington, MN), 7 Delta (Depuy, Warsaw, IN), and 1 Anatomical Shoulder (Zimmer, Warsaw, IN). The humeral component was cemented in 38 of the 286 shoulders (13%), and press-fit humeral fixation was used in the remaining 248 (87%), with a current trend toward using press-fit fixation. Humeral components were placed in the retroversion specific to their respective manufacturer's recommendations.

Postoperative data were collected prospectively during the patients' clinical follow-up visits at intervals of 2 weeks, 6 weeks, 3 months, 6 months, and 12 months and annually after the RTSA. They were placed in the master database. Shoulder active and passive ranges of motion, including both forward elevation and external rotation arcs, were measured in degrees with the use of a goniometer. Lag was determined as the difference between active and passive range of motion in a particular motion plane. Shoulder forward elevation and external rotation strength were measured in pounds (lb.) with the use of a digital electronic dynamometer (Lafayette Manual Muscle Testing System Model

01165). All range of motion and strength data were obtained by a hand therapist, physical therapist, or certified athletic trainer in a standardized manner. Grashey anteroposterior and axillary lateral view radiographs were obtained at postoperative visits and assessed by the treating surgeons using a standardized scoring chart. Specific radiographic findings were recorded including radiolucent lines around the humeral or glenoid components and evidence of scapular notching. Information from validated outcome scoring systems was collected both preoperatively and postoperatively. These included the University of California at Los Angeles (UCLA) score, Constant score, American Shoulder and Elbow Surgeon (ASES) Standardized Shoulder Assessment Form, Shoulder Pain and Disability Index (SPADI), Short Form 12 (SF-12) Health Survey, and Simple Shoulder Test (SST). Intraoperative rotator cuff integrity was interpreted through review of the assessment dictated in the operative note and was subjectively graded as "absent," "poor quality," or "good quality" for the supraspinatus, infraspinatus, teres minor, and subscapularis tendons individually. Preoperative data had been recorded in 248 of the 286 shoulders (87%).

Statistical Analysis

Statistical analyses were conducted using SAS version 9.3 (Cary, NC). Wilcoxon rank-sum tests were used to determine group differences on ordinal or numeric measures. χ^2 or Fisher's exact (in the case of data sparseness) tests were used to compare groups on binary or categorical measures. For determination of preoperative probabilities, a logistic regression model and area under the curve model were used. All testing was 2-sided. The level of significance was set at .05.

Results

Mean postoperative active shoulder elevation was 114.9 $\pm$ 24.7° for all 286 initial study subjects. Of these subjects, group I was comprised of 29 (10.1%) shoulders that fell within the 90th percentile of active shoulder elevation (average: 149.8° active and 156.3° passive). Group II included 28 (9.8%) patients that never achieved at least 90° active shoulder elevation (average: 63.3° active and 108.9° passive) 12 months postoperatively.

The chance of achieving the 90th percentile of active forward elevation (group I) compared to the 10th percentile (group II) had a statistically significant preoperative ($p < 0.05$) correlation with relatively younger age (P .0245), lower ASA score (P .045), increased elevation active range of motion ($P < .0001$), and improved preoperative Constant score (P .0029). Postoperative significant factors include increased elevation strength ($P < .0001$), increased external rotation strength (P .0026), increased elevation passive range of motion ($P < .0001$), decreased elevation lag ($P < .0001$), increased external rotation active range of motion ($P < .0419$), increased external rotation passive range of motion (P .0346), improved postoperative UCLA score ($P < .0001$), improved postoperative Constant score ($P < .0001$), improved postoperative ASES score ($P < .0001$), improved postoperative SPADI score ($P < .0001$), and improved postoperative SST score ($P < .0001$). These results are summarized in Tables 1 and 2.

Patient Demographics, ASA Score, and Medical History

Patients had a mean age at the time of surgery of 66.7 $\pm$ 6.0 years in group I and 71.8 $\pm$ 9.9 years in group II (P .0245). No statistically significant correlation was identified between group stratification and the other demographic variables, including gender (P .1344) and ethnicity (P .3676). A statistically significant correlation was identified between group I and lower ASA score (P .045). Incidentally, a statistically significant direct correlation was also identified between group I and a history of hypertension (P .0035). There was no statistically significant correlation, however, among the remaining medical comorbidities, which included history of heart disease (P .9638), history of diabetes mellitus (P .2455), history of tobacco use (P .3045), body mass index (P .4156), operative diagnosis (P .5087), and history of previous ipsilateral shoulder surgery (P .9164). Of note, the operative diagnoses in group I included rotator cuff tear arthropathy in 23 shoulders (40.4%), osteoarthritis with rotator cuff deficiency in 5 shoulders (8.8%), and proximal humerus fracture in 1 shoulder (1.8%), while those in group II included rotator cuff tear arthropathy in 25 shoulders (43.9%), osteoarthritis with rotator cuff deficiency in 2 shoulders (3.5%), and proximal humerus fracture in 1 shoulder (1.8%).

Shoulder Strength

Final postoperative shoulder strength was measured in elevation and external rotation. Mean maximum shoulder elevation strength was measured at 14.7 $\pm$ 7.2 lb. in group I versus 7.4 $\pm$ 4.8 lb. in group II ($P < .0001$). Mean shoulder external rotation strength was measured at 11.1 $\pm$ 5.5 lb. in group I versus 6.9 $\pm$ 3.2 lb. in group II ($P < .0026$).

Shoulder Active Range of Motion

Preoperative shoulder active elevation was 106.3 $\pm$ 30° for group I and 57.5 $\pm$ 27.3° for group II ($P < .0001$).

Table 1. Mean Shoulder Elevation Active Range of Motion and SD for Group I and Group II Among Subgroups Using Numerical Data.

	Group I			Group II			
Variable	N	Mean	SD	N	Mean	SD	*P* (*t* test)
Age	29	66.7	6.0	28	71.8	9.9	**.0245**
BMI	27	31.1	5.82	21	29.5	7.2	.4156
Pre-op elevation AROM	25	106.3	30.0	24	57.5	27.3	**<.0001**
Elevation Strength	28	14.7	7.2	28	7.4	4.8	**<.0001**
External Rotation Strength	24	11.1	5.5	23	6.9	3.2	**.0026**
Elevation PROM	29	156.3	5.5	28	108.9	27.8	**<.0001**
Elevation lag (PROM-AROM)	29	6.5	5.4	28	45.6	24.9	**<.0001**
External rotation AROM	26	31.0	16.2	28	21.2	18.3	**.0419**
External rotation PROM	25	49.9	16.2	28	39.8	17.8	**.0346**
External rotation lag (PROM-AROM)	29	15.2	12.0	28	18.5	16.0	.3804
Constant normalized pre-op	18	46.7	12.2	14	32.8	11.8	**.0029**
Constant raw pre-op	18	41.0	11.4	15	25.8	11.4	**.0007**
ASES pre-op	19	37.7	14.2	17	35.7	17.8	.7091
SF-12 MCS pre-op	19	19.5	4.4	16	18.4	4.4	.4732
SF-12 PCS pre-op	19	12.0	3.0	16	11.0	2.3	.2713
SF-12 total pre-op	19	31.5	6.7	16	29.4	5.5	.3195
SPADI pre-op	20	66.2	15.6	17	69.7	12.8	.4581
SPADI 130 pre-op	22	85.3	20.7	21	88.9	26.0	.6167
SST-12 pre-op	19	3.9	3.1	17	2.8	1.7	.1979
UCLA pre-op	16	14.5	2.9	13	12.3	3.5	.0844
Constant normalized post-op	26	78.4	11.6	25	44.3	10.6	**<.0001**
Constant raw post-op	26	68.0	10.0	26	36.7	9.8	**<.0001**
ASES post-op	27	82.6	18.0	27	61.5	19.4	**.0001**
SF-12 MCS post-op	27	20.6	5.5	26	20.5	4.4	.9465
SF-12 PCS post-op	27	14.3	3.6	26	13.8	3.2	.6027
SF-12 total post-op	27	34.9	8.3	26	34.3	6.8	.7804
SPADI post-op	27	17.2	17.5	26	46.2	22.0	**<.0001**
SPADI 130 post-op	27	22.6	22.0	26	61.9	27.8	**<.0001**
SST-12 post-op	27	10.3	2.1	27	5.6	2.6	**<.0001**
UCLA post-op	26	29.7	5.2	25	21.2	6.1	**<.0001**

Abbreviations: AROM, active range of motion; ASES, American Shoulder and Elbow Surgeon; BMI, body mass index; MCS, mental composite score; PCS, physical composite score; PROM, passive range of motion; SD, standard deviation; SF-12, Short Form 12; SPADI, Shoulder Pain and Disability Index; SST, Simple Shoulder Test; UCLA, University of California at Los Angeles.
Significant results ($P < .05$) are in bold.

Final postoperative shoulder active external rotation was measured at $31.0 \pm 16.2°$ for group I and $21.2 \pm 18.3°$ for group II ($P < .0419$). Final postoperative shoulder elevation lag was measured at $6.5 \pm 5.4°$ for group I and $45.6 \pm 24.9°$ for group II ($P < .0001$), as determined from mean active elevation of 149.8° and 63.3°, respectively. No statistically significant correlation was found with regard to final postoperative external rotation lag, which was measured at $15.2 \pm 12.0°$ for group I and $18.5 \pm 16.0°$ for group II (*P* .3804).

Shoulder Passive Range of Motion

Final postoperative passive shoulder elevation was $156.3 \pm 5.5°$ for group I and $108.9 \pm 27.8°$ for group II ($P < .0001$). Final postoperative shoulder passive external rotation was measured at $49.9 \pm 16.2°$ for group I and $39.8 \pm 17.8°$ for group II (*P* .0346).

Validated Outcome Scores

Regarding preoperative validated outcome scores, a statistically significant direct correlation was identified between group I and improved Constant score (*P* .0029), yet no statistically significant correlation was found with regard to UCLA score (*P* .0844), ASES score (*P* .7091), SPADI score (*P* .4581), SF-12 score (*P* .3195), or SST score (*P* .1979) preoperatively. On the other hand, upon assessing postoperative validated outcome scores, a statistically significant direct correlation was identified between group I and improved UCLA score ($P < .0001$), Constant score ($P < .0001$), ASES score (*P* .0001), SPADI score ($P < .0001$), and SST score ($P < .0001$).

Complication Rate

The complication rate was not significantly different between the 2 groups (*P* .9798). Perioperative

Table 2. Mean Shoulder Elevation Active Range of Motion and Standard Deviation for Group I and Group II Among Subgroups Using Categorical or Binary Data.

		Group I		Group II		
Variable	Value	N	%	N	%	*P* (χ^2 Test)
Gender	Male	15	26.3	9	15.8	.1344
	Female	14	24.6	19	33.3	
Ethnicity	African American	1	1.8	0	0	.3676
	Caucasian	26	47.3	27	49.1	
	Hispanic	1	1.8	0	0	
Operative diagnosis	RCA	23	40.4	25	43.9	.5087
	OA RC Def.	5	8.8	2	3.5	
	Prox. Hum. Fx.	1	1.8	1	1.8	
	Irrep. RC tear	0	0	0	0	
ASA score	>3	17	60.7	19	86.4	**.045**
HTN	Yes	16	55.2	5	17.9	**.0035**
	No	13	22.8	23	40.4	
Heart disease	Yes	3	5.3	3	5.3	.9638
	No	26	45.6	25	43.9	
Diabetes mellitus	Yes	5	8.8	2	3.5	.2455
	No	24	42.1	26	45.6	
Chronic liver disease	Yes	0	0	0	0	1
	No	29	50.9	28	49.1	
Chronic renal failure	Yes	0	0	0	0	1
	No	29	50.9	28	49.1	
Tobacco use	Yes	0	0	1	1.8	.3045
	No	29	50.9	27	47.4	
Previous shoulder surgery	Yes	11	19.3	11	19.3	.9164
	No	18	31.6	17	29.8	
Intraop complication	Yes	1	1.8	1	1.8	.9798
	No	28	49.1	27	47.4	
Post-op complication	Yes	1	1.8	1	1.8	.9798
	No	28	49.1	27	47.4	
Humeral radiolucent lines	Yes	2	5.4	1	2.7	.8667
	No	21	56.8	13	35.1	
Glenoid radiolucent lines	Yes	0	0	0	0	1
	No	23	60.5	15	39.5	
Scapular notching	Yes	0	0	0	0	1
	No	23	60.5	15	39.5	
Intraop supraspinatus integrity	Absent	20	37.7	18	34.0	.6274
	Poor	9	17.0	6	11.3	
	Good	0	0	0	0	
Intraop infraspinatus integrity	Absent	14	28.0	12	24.0	.3823
	Poor	6	12.0	6	12.0	
	Good	9	18.0	3	6.0	
Intraop teres minor integrity	Absent	2	4.0	6	12.0	.0781
	Poor	7	14.0	6	12.0	
	Good	20	40.0	9	18.0	
Intraop subscapularis integrity	Absent	5	9.6	4	7.7	.9298
	Poor	17	32.7	17	32.7	
	Good	5	9.6	4	7.7	

Abbreviations: ASA, American Society of Anesthesiologists; HTN, hypertension; OA RC Def., osteoarthritis with rotator cuff deficiency; Irrep. RC tear, irreparable rotator cuff tear; Prox. Hum. Fx., proximal humerus fracture; RCA, rotator cuff arthropathy.
Significant results ($P < .05$) are in bold.

complications were documented in 16 (5.6%) of the 286 subjects by 12 months postoperatively. These complications include 1 intraoperative humerus greater tuberosity fracture, 8 postoperative periprosthetic humerus fractures (3 of which were treated surgically), 2 acromion fractures treated conservatively, 2 dislocations (1 of which was treated with component revision for chronic instability), 2 cases of glenoid baseplate aseptic loosening treated with component revision, and 1 infection treated with staged revision of the prosthesis and antibiotics. It should be noted, however, that the presence of intraoperative or postoperative complications did not correlate with shoulder active elevation postoperatively.

Radiographic Findings and Intraoperative Rotator Cuff Integrity

No statistically significant correlation was identified between the 2 groups and radiolucent lines around the humeral component (*P* .8667). No subjects in either group were found to have radiolucent lines around the glenoid component or evidence of scapular notching. Lastly, no statistically significant correlation was identified between group stratification and subjective intraoperative supraspinatus (*P* .6274), infraspinatus (*P* .3823), teres minor (.0781), or subscapularis (*P* .9298) integrity.

Determination of Preoperative Clinical Guidelines

As mentioned previously, the 3 statistically significant, quantitative preoperative variables demonstrating direct correlation with group I achievement include relatively younger age (*P* .0245), increased preoperative active elevation ($P < .0001$), and improved preoperative Constant score (*P* .0029). These variables were then run in a multivariate logistic regression model, and preoperative active elevation was determined to be the only variable of the 3 that demonstrated significant independent relation to the dependent group variable. Therefore, an area under the curve model was constructed using preoperative active elevation to determine predictive preoperative clinical guidelines for achievement of group I placement. This model demonstrates that preoperative active elevation range of motion of less than 55° predicts a less than 19% probability of group I achievement, 55° to 79° predicts a 19% to 50% probability of group I achievement, 80° to 104° predicts a 50% to 82% probability of group I achievement, and greater than 104° predicts a greater than 82% probability of group I achievement.

Discussion

In contrast to the breadth of research investigating the biomechanical factors integral to RTSA functionality, there is a paucity of literature focusing on the clinical predictors for successful outcomes with RTSA. It has been demonstrated that RTSA for posttraumatic arthritis or as a revision procedure yields less satisfactory functional outcomes in comparison to primary RTSA, and this in turn has led some to pose questions regarding the specific clinical factors that play a role in postoperative functional results.[18–22] Additionally, elevated ASA score and obesity have been shown to have a correlation with postoperative complications, such as prosthetic failure, after primary total shoulder arthroplasty.[16,17] With this said, few studies to date in the literature have investigated functional outcomes and their relation to specific clinical variables in primary RTSA.[18]

By examining active shoulder elevation 12 months postoperatively, we were able to identify subjects as having high function (90th percentile, achieving at least 145° active forward elevation) or poor functionality (10th percentile, achieving less than 90° active forward elevation). By setting group stratification as the dependent outcome variable, we found several factors that predict improved functionality after primary RTSA. These variables that significantly ($P < .05$) directly correlate with the achievement of at least 145° (in contrast to less than 90°) of active shoulder elevation 12 months postoperatively include relatively younger age (*P* .0245), lower ASA score (*P* .045), increased preoperative active elevation ($P < .0001$), improved preoperative Constant score (*P* .0029), increased elevation strength ($P < .0001$), increased external rotation strength (*P* .0026), increased passive elevation ($P < .0001$), decreased elevation lag ($P < .0001$), increased active external rotation ($P < .0419$), increased passive external rotation (*P* .0346), improved postoperative UCLA score ($P < .0001$), improved postoperative Constant score ($P < .0001$), improved postoperative ASES score ($P < .0001$), improved postoperative SPADI score ($P < .0001$), and improved postoperative SST score ($P < .0001$).

First, our study demonstrates that relatively younger patients exhibit improved shoulder elevation by 1 year in comparison to their older counterparts. With that said, however, it is important to consider that this information cannot be applied to all young age groups, as our study is comparing a mean age of 67 years in group I to 72 years in group II, which may not be clinically significant. While patients younger than 60 years can gain substantial functional improvement after RTSA, previous research has suggested that overall satisfaction is less than in older patients.[23] Second, our study suggests that improved shoulder elevation by 1 year may correlate with a lower ASA score. Although all subjects in our study had an ASA score of either 2 or 3, there were a significantly increased number of ASA 3 scores within group II. This suggests that, in addition to increasing the complication risk,[16] elevated ASA score may be predictive of worse functional outcomes after RTSA. However, additional studies focused on a larger cohort of patients with a wider range of ASA score could help elucidate this finding.

Our study also shows that preoperative active elevation range of motion is the strongest tested independent predictor of postoperative function. This, in addition to intraoperative motion, has also been implicated as an important predictor of postoperative elevation by Schwartz et al.[18] Subjects in group I had a mean preoperative elevation of $106.3 \pm 30°$ compared to $57.5 \pm 27.3°$ in group II ($P < .0001$). Using the area under the curve model, it was determined that subjects able to achieve at least 105° of preoperative active elevation demonstrated a probability of at least 82% of achieving a chance of ≥145 degrees of active forward elevation. Preoperative active motion may help predict postoperative active forward elevation for the majority of patients undergoing RTSA. It should be noted that this cannot be applied to the cohort of patients undergoing treatment for fracture.

It is also interesting to note that the preoperative validated outcome scores most predictive of improved elevation 1 year postoperatively were the Constant score (P .0029) and the UCLA score (P .0844). These validated outcome scoring systems are the only 2 in this study that incorporate quantitatively measured active shoulder elevation. The strong correlation between Constant score and function in RTSA has also been demonstrated in a study by Sabesan et al.[24] The remaining preoperative scoring systems, including the ASES score (P .7091), SPADI score (P .4581), SF-12 score (P .3195), and SST score (P .1979), demonstrated no statistical correlation.

While the significance of passive shoulder elevation would seem to suggest that stiffness plays a role in the primary outcome variable, this may not necessarily be true. To better understand the exact function of passive shoulder elevation, we also tested for elevation lag, which was determined by the difference between passive and active shoulder elevation 12 months postoperatively. We found that in addition to having decreased passive shoulder elevation measurements, subjects unable to achieve 90° of forward elevation (group II) demonstrated significantly greater lag ($P < .0001$). Furthermore, average postoperative passive shoulder elevation for group II was $108.8 \pm 27.8°$, indicating that a majority of these subjects were able to achieve at least 90° of elevation passively.

Active shoulder elevation was used as the primary outcome variable in our study for several reasons. For 1, elevation to at least 90° is quickly and accurately assessed by health-care providers in the clinic and is easily explained to patients during preoperative counseling on the ultimate goals of surgery. Furthermore, it is commonly held that active shoulder elevation of at least 90° is essential for the completion of many activities of daily living. This has been supported by a recent prospective 3D motion analysis study demonstrating that glenohumeral elevation of up to 95° was utilized for tested activities of daily living following RTSA.[12] Our study substantiates the ability to use active shoulder elevation as a simple marker of overall function, as improved active shoulder elevation 1 year postoperatively correlated strongly with increased elevation strength ($P < .0001$), increased external rotation strength (P .0026), increased active external rotation ($P < .0419$), and improved validated outcome scores, including the UCLA ($P < .0001$), Constant ($P < .0001$), ASES ($P < .0001$), SPADI ($P < .0001$), and SST ($P < .0001$) scores.

The principal strengths of this study are that it is well powered, and the data were prospectively collected. From a total subject number of 286 consecutive primary RTSA surgeries, 29 (10.1%) subjects were designated as group I and 28 (9.8%) were designated as group II, for a total number of 57 subjects used in the final analysis. Furthermore, data collection and storage were standardized, and all shoulder range of motion and strength measurements were quantitatively obtained by a licensed practitioner at uniform intervals.

Some weaknesses are inherent in the retrospective nature of our study as well as its use of the database. For instance, data entry was not blinded. However, data were quantitatively measured and entered in a prospective manner at regular intervals prior to the initiation of this study, thereby reducing the influence of any potential measurement bias. Another weakness inherent to the use of the database is the potential for incomplete data among the independent variables examined within the subject population. Of the initial 286 shoulders, 248 (86.7%) had preoperative information entered into the database.

The results of our study offer insight into significant clinical factors that correlate with the ability to achieve functional active shoulder elevation after primary RTSA. The results of our study also shed light on potential future directions in related research. One future direction would be assessing anatomic factors, such as humeral distalization or lateralization, which may affect postoperative shoulder function after primary RTSA. This has been shown by Jobin et al. to be an important factor in maximizing function through active shoulder elevation in patients with rotator cuff tear arthropathy.[25] Also, while subjectively assessed intraoperative rotator cuff integrity did not significantly correlate with active shoulder elevation in our study, there is literature to suggest that fatty infiltration of the infraspinatus does impact functional outcomes in RTSA.[26] Therefore, it may be valuable to investigate rotator cuff integrity objectively through magnetic resonance imaging and its impact on active shoulder elevation after RTSA.

Conclusion

The purpose of our study is to investigate the functional outcome, as measured by active shoulder forward elevation 12 months postoperatively, following primary RTSA and its correlation with selected clinical patient factors. In our study, active shoulder forward elevation of at least 90° was achieved 12 months postoperatively following primary RTSA in 90.2% of subjects. Upon comparison of the 90th percentile of postoperative active elevation (at least 145°) with the 10th percentile, there is a significant direct correlation between improved postoperative active shoulder elevation and preoperative measures of relatively younger age, lower ASA score, increased preoperative active elevation, and improved preoperative Constant score. There is also a significant direct correlation between improved postoperative active shoulder elevation and postoperative measures of increased strength (in forward elevation and external rotation), increased passive elevation, decreased elevation lag, increased active and passive external rotation as well as nearly all tested validated outcome scores. These findings are important, as they may assist surgeons by revealing significant factors in the ability to function through activities of daily living after primary RTSA. When assessing significant preoperative variables, the only independent predictor of improved postoperative forward elevation was preoperative active forward elevation. Knowledge of such factors allows surgeons to appropriately counsel patients on the functional prognosis following primary RTSA.

Acknowledgments

The authors thank Statistician Cynthia Garvin, PhD, for statistical analysis.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Thomas W Wright, MD, has received royalties and research support from Exactech, Inc. Kevin W Farmer, MD, has served as a consultant for Exactech, Inc. No company or organization had any input into the study design, protocol, testing, or data analysis. All other authors, their immediate family, and any research foundation with which they are affiliated did not receive financial payments or other benefits from any commercial entity related to the subject of this study.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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