



# Predicting outstanding results after anatomic total shoulder arthroplasty using percentage of maximal outcome improvement

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**Background:** The purpose of this study was to determine whether thresholds in the percentage of maximal improvement in the Simple Shoulder Test (SST) or American Shoulder and Elbow Surgeons (ASES) score exist for predicting “excellent” patient satisfaction after total shoulder arthroplasty (TSA).

**Methods:** A retrospective query identified patients who underwent TSA with a minimum of 2 years’ follow-up. Preoperative and postoperative SST and ASES scores and postoperative patient satisfaction were recorded. Receiver operating characteristic curve analyses were performed to determine thresholds in the percentage of maximal improvement in the SST and ASES scores that predict excellent satisfaction. Univariate and multivariate analyses determined preoperative factors that predicted achievement of these thresholds.

**Results:** A total of 301 and 319 patients had at least 2 years’ follow-up for the SST score and ASES score, respectively. We determined 72.1% of maximal improvement in the SST score to be the threshold for excellent satisfaction (area under the curve, 0.777; 95% confidence interval, 0.712-0.841;  $P < .001$ ). We determined 75.6% of maximal improvement in the ASES score to be the threshold for excellent satisfaction (area under the curve, 0.799; 95% confidence interval, 0.743-0.856;  $P < .001$ ). Both groups showed significant positive correlations between percentage of maximal score achieved and excellent satisfaction ( $r = 0.396$  for SST score [ $P < .001$ ] and  $r = 0.325$  for ASES score [ $P < .001$ ]). Younger age was the only independent predictor for achieving the SST score threshold. No independent predictors existed for the ASES score threshold.

**Conclusion:** Achievement of 72.1% of maximal SST score improvement and achievement of 75.6% of maximal ASES score improvement represent thresholds for achievement of excellent satisfaction after TSA. Most preoperative factors did not have an impact on the likelihood of achieving these thresholds.

**Level of evidence:** Basic Science Study; Development or Validation of Outcome Instrument

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**Keywords:** Percentage of maximal improvement; Simple Shoulder Test; American Shoulder and Elbow Surgeons score; satisfaction; total shoulder arthroplasty; predictors

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Anatomic total shoulder arthroplasty (TSA) is a primary method for treating patients with glenohumeral osteoarthritis<sup>2</sup> and has been shown to produce favorable long-term results.<sup>7</sup> Patient-reported outcome measures (PROMs) have become an important tool for tracking subjective outcomes after TSA and are gaining popularity because of their convenience and utility. Several PROMs have been validated for use in monitoring outcomes after shoulder surgery, including the Constant-Murley score,<sup>6</sup> Western Ontario Osteoarthritis of the Shoulder index,<sup>14</sup> Single Assessment Numeric Evaluation,<sup>26</sup> American Shoulder and Elbow Surgeons (ASES) score, and Simple Shoulder Test (SST).<sup>10,20</sup> A number of studies have used these scores to determine the minimal improvement needed to achieve a clinically significant difference, often anchoring these values to patient satisfaction.<sup>21,22,25</sup> However, ceiling effects remain a concern as patients may achieve high PROM scores but not reach the minimal clinically significant difference owing to having higher baseline scores.<sup>8,21</sup>

Gilmer et al<sup>8</sup> previously described a method for analyzing improvement in the SST score that sets a higher standard for defining a positive outcome after shoulder surgery and limits potential ceiling effects. They defined a “better” outcome as an improvement of greater than 30% of the maximal possible improvement from the baseline SST score. Matsen et al<sup>15</sup> recently used this methodology to perform a multivariate analysis and developed a predictive model based on factors associated with better outcomes. Although this methodology has shown utility in establishing clinical benchmarks for a better result, no study has explored what is necessary to achieve an excellent level of satisfaction.

In the spirit of optimism, orthopedic surgeons and patients alike hope to achieve the highest level of satisfaction with elective surgical procedures such as TSA. This emphasis on achieving excellent patient satisfaction has been a focus of the modern US health care system, exemplified more recently by affixing reimbursement models to excellent HCAHPS (Hospital Consumer Assessment of Healthcare Providers and Systems) survey scores.<sup>1,5</sup> It is therefore of increasing importance to understand what factors contribute to the achievement of the highest level of patient satisfaction. The primary purpose of this study was to determine whether there are thresholds in the percentage of maximal SST or ASES score improvement that are associated with a higher incidence of “excellent” patient satisfaction after TSA. A secondary purpose was to determine whether specific preoperative factors predict the achievement of these thresholds.

## Methods

A retrospective query of our institution’s shoulder and elbow surgery registry was performed for patients who underwent anatomic TSA (Current Procedural Terminology code 23472) from

2007 to 2015. Patients were included based on the availability of preoperative and postoperative ASES and SST score data with at least 2 years’ follow-up. We excluded patients who underwent arthroplasty for fracture, reverse shoulder arthroplasty, or hemiarthroplasty; who had incomplete data; or who had less than 2 years’ follow-up. All procedures were performed by the senior author, using a deltopectoral approach and either the Encore Foundation (2007-2009; DJO Surgical, Austin, TX, USA) or Turon (2009-2015; DJO Surgical) anatomic TSA system. All patients were treated with an identical postoperative rehabilitation protocol using a shoulder immobilizer for the first 6 weeks and patient-directed pendulum exercises, followed by 6 weeks of active stretching and delayed strengthening for 3 months. ASES and SST scores are routinely collected from patients at preoperative and postoperative intervals as a part of the registry protocol. Postoperative patient satisfaction is reported as excellent, good, satisfactory, or unsatisfactory.

The percentage of maximal improvement achieved in the SST score was calculated based on previous methodology.<sup>7</sup> We then extrapolated this methodology to calculate the percentage of maximal improvement achieved in the ASES score. This was calculated for both the SST and ASES scores using the following formula: [(Outcome score at most recent follow-up – Preoperative outcome score) × 100%]/(Highest possible outcome score – Preoperative outcome score). The association between the percentage of maximal improvement achieved and excellent satisfaction was analyzed.

Receiver operating characteristic (ROC) curve analyses were performed to determine thresholds (cutoff points) of maximal possible improvement at 2 years postoperatively for both the SST and ASES scores independently. Thresholds were defined as the point at which both specificity and sensitivity were maximized in predicting the highest level of excellent satisfaction results.<sup>4</sup> These thresholds were reaffirmed with  $\chi^2$  analyses.

All preoperative variables were retrospectively obtained using the surgical repository. Patient demographic characteristics and comorbidities are noted at each patient’s preoperative appointment. Active elevation, abduction, external rotation, and internal rotation are measured via best-effort goniometer measurements. Preoperative PROMs including the SST, ASES score, Single Assessment Numeric Evaluation, visual analog scale for pain, visual analog scale for function, and Mental Component Summary (MCS) and Physical Component Summary (PCS) of the Short Form 12 Health Survey were collected. Patients were asked preoperatively about the presence of shoulder pain, nightly shoulder pain, shoulder instability, or mechanical symptoms (catching, locking, or grinding of the shoulder joint). Narcotic and nonsteroidal anti-inflammatory medication use before surgery was also assessed.

Univariate logistic regression analyses were used to determine preoperative predictors of achievement of the threshold in the percentage of maximal outcome improvement for both the SST and ASES scores. Variables showing significance were incorporated into a multivariate model to determine independent predictors for achieving thresholds.

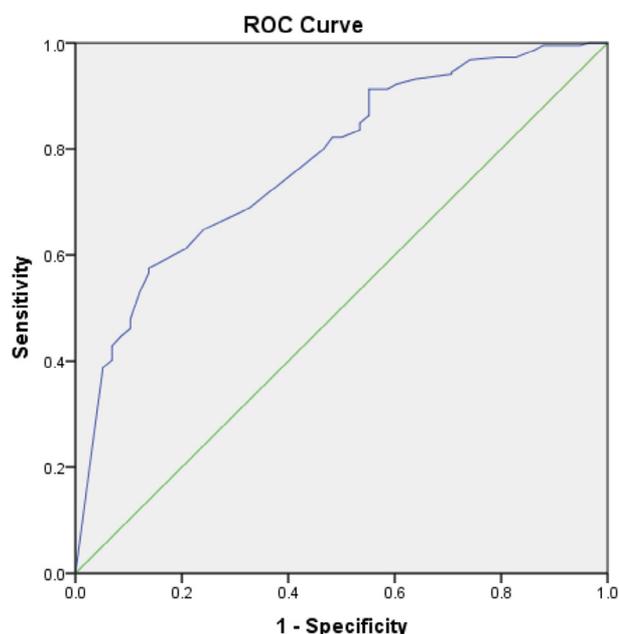
Paired-samples *t* tests and linear regression analyses were used to determine significant differences and relationships between continuous variables. We used  $\chi^2$  analyses to assess dichotomous variables. Statistical analyses were performed using SPSS software (version 23.0; IBM, Armonk, NY, USA). Significance was set at  $P < .05$ .

## Results

### Threshold for percentage of maximal improvement in SST score

Of the 439 patients with preoperative data, 301 met the inclusion criteria and had at least 2 years' follow-up for the SST score and satisfaction (mean follow-up, 50 months; range, 24-124 months). There were 147 male patients (48.8%) and 153 female patients (50.8%) (in 1 patient, sex was not recorded). The mean age was 70.6 years (standard deviation [SD], 8.3 years; range, 32.0-88.9 years). The distributions of preoperative and most recent postoperative SST scores are shown in Figure 1. The mean preoperative SST score was 3.29 (SD, 2.67; range, 0-12). The average SST score at the most recent follow-up visit was 9.21 (SD, 2.95; range, 1-12), constituting a mean increase of 5.92 (SD, 3.54; range, -9 to 12;  $P < .001$ ). Of the patients, 227 (75.42%) rated their surgical outcomes as excellent; 43 (14.29%), as good; 23 (7.64%), as satisfactory; and 8 (2.66%), as unsatisfactory.

Two patients reported a preoperative SST score of 12, and thus calculation of the percentage of maximal improvement achieved was not possible for these patients (division by 0). By use of data from the 277 patients with postoperative SST score improvement, ROC curve analysis determined 72.1% of maximal improvement in the SST score as the threshold for maximal predictability of excellent satisfaction (area under



Diagonal segments are produced by ties.

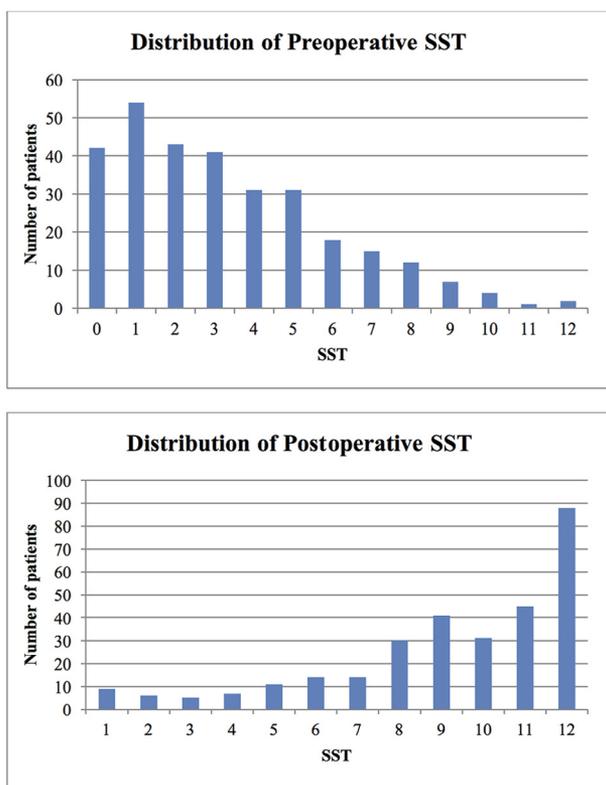
**Figure 2** Receiver operating characteristic (ROC) curve for Simple Shoulder Test scores as a predictor of excellent satisfaction (area under the curve, 0.777; 95% confidence interval, 0.712-0.841;  $P < .001$ ).

the curve, 0.777, 95% confidence interval, 0.712-0.841;  $P < .001$ ; Fig. 2). Patients achieving the threshold of at least 72.1% of maximal SST score improvement had significantly higher rates of excellent satisfaction than those below this threshold (89.2% vs 58.2%,  $P < .001$ ). For all patients with postoperative SST score improvement (278 patients, 92.1%), there was a significant positive correlation between percentage of maximal SST score achieved and excellent satisfaction ( $r = 0.396$ ,  $P < .001$ ; Fig. 3).

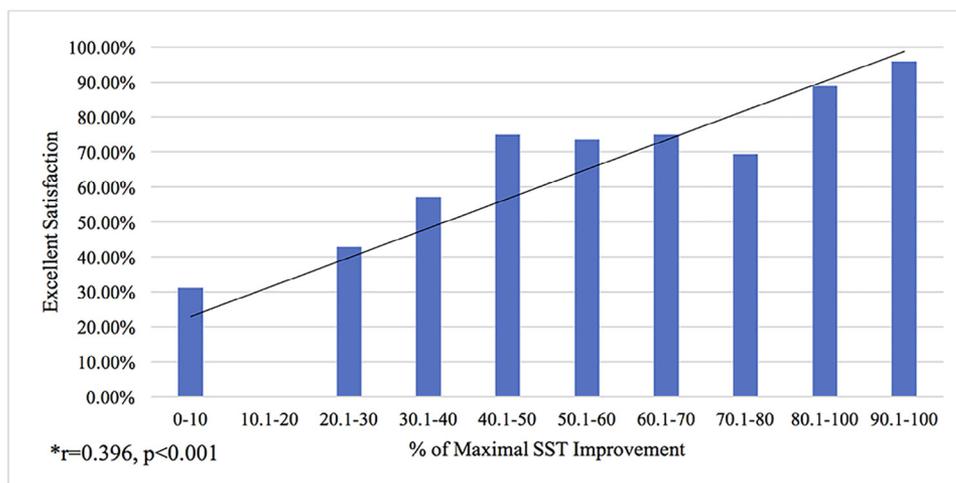
Univariate analysis determined younger age (odds ratio [OR], 0.954;  $P = .005$ ), greater height (OR, 1.038;  $P = .001$ ), male sex (OR, 0.473;  $P = .003$ ), greater baseline SST score (OR, 1.118;  $P = .035$ ) and Short Form 12 PCS score (OR, 1.043;  $P = .023$ ), greater preoperative abduction (OR, 1.015;  $P = .044$ ), and absence of osteoporosis (OR, 0.383;  $P = .019$ ) to be predictors of achieving the threshold in the percentage of maximal SST score improvement (Table I). However, multivariate analysis determined younger age (OR, 0.957;  $P = .048$ ) as the only independent predictor (Table II).

### Threshold for percentage of maximal improvement in ASES score

Of the 439 patients with preoperative data, 319 met the inclusion criteria and had minimum 2-year follow-up data for the ASES score and satisfaction (mean follow-up, 49 months; range, 24-124 months). The average age was 70.3 years (SD, 8.2 years; range, 32.0-88.9 years). The distributions of preoperative and most recent postoperative ASES scores are



**Figure 1** Simple Shoulder Test (SST) scores preoperatively and postoperatively.



**Figure 3** Percentage of patients with excellent satisfaction for 10% increments in maximal Simple Shoulder Test (SST) score improvement achieved.

shown in Figure 4. The mean ASES score increased from 30.94 (SD, 17.13; range, 0-86.70) preoperatively to 80.52 (SD, 21.69; range, 5.00-100.00) postoperatively, representing an average increase of 49.58 (SD, 25.48; range, -66.60 to 100.00;  $P < .001$ ). Of the patients, 241 (75.55%) rated their surgical outcomes as excellent whereas 45 (14.11%) rated their outcomes as good; 24 (7.52%), as satisfactory; and 9 (2.82%), as unsatisfactory.

ROC curve analysis determined that a threshold of 75.6% of maximal improvement in the ASES score had maximal predictability for determining the presence of excellent satisfaction (area under the curve, 0.799; 95% confidence interval, 0.743-0.856;  $P < .001$ ; Fig. 5). Patients achieving this threshold had significantly higher rates of excellent satisfaction than those who did not achieve it (90.7% vs 52.4%,  $P < .001$ ). For all patients with postoperative ASES score improvement (305 patients, 95.3%), there was a significant positive correlation between percentage of maximal ASES score achieved and excellent satisfaction ( $r = 0.325$ ,  $P < .001$ ; Fig. 6).

Univariate analysis determined that greater height (OR, 1.024;  $P = .033$ ) and greater baseline MCS score (OR, 1.048;  $P = .001$ ) were predictors of achieving the threshold in the percentage of maximal ASES score improvement (Table III). No independent predictors of this threshold were found in multivariate analysis (Table IV).

## Discussion

The results of our study show that there is a significant positive correlation between the percentage of maximal improvement achieved in both the ASES and SST scores and attaining excellent postoperative satisfaction after anatomic TSA. Achievement of 72.1% of maximal improvement in the SST score or 75.6% of maximal improvement in the ASES score represents a threshold for defining excellent satisfaction after anatomic TSA. Furthermore, our study determined

there are no significant independent predictors of achieving the threshold in the percentage of maximal ASES score improvement. Younger age was the only significant independent predictor of achieving the threshold in the percentage of maximal SST score improvement; however, the OR was just under 1.

Gilmer et al<sup>8</sup> previously established the concept of using the percentage of maximal improvement achieved in the SST score as a measure of postoperative improvement. This methodology limits ceiling effects that can occur when attempting to determine whether a patient has obtained a minimal clinically important difference (MCID) in outcome measures postoperatively. Although most patients report low functional scores preoperatively, there are some patients who report relatively high baseline scores, which make it more difficult to achieve an MCID postoperatively.

MCIDs have been reported for shoulder arthroplasty, and these often vary for different patient populations. An SST score of 2.2 was found to be the MCID in a study by van Kampen et al.<sup>24</sup> Tashjian et al<sup>22</sup> determined that patients must achieve an increase of at least 2.4 points in the SST score and 21 points in the ASES score for an MCID to be observed. Werner et al<sup>25</sup> found an MCID of  $13.5 \pm 4.5$  for the ASES score and reported that a 23-point improvement was required for a substantial clinical benefit. Jacobs et al<sup>11</sup> determined that patients who did not achieve an increase of at least 12 points in the ASES score were 19 times more likely to be dissatisfied with their surgery. For those patients who report high baseline preoperative scores, achievement of the MCID may not be possible, even in cases in which an excellent result was achieved.

Although many studies have reported a high percentage of patients reporting overall satisfaction after shoulder arthroplasty,<sup>13,17-19,23</sup> less attention has been directed toward the achievement of excellent results. Few studies have linked outcome measures to excellent patient satisfaction, and no study, to our knowledge, has done so using the percentage

**Table I** Univariate logistic regression of preoperative variables in patients with and without outstanding results according to SST score undergoing anatomic total shoulder arthroplasty

Variable	OR (95% CI)	P value
Surgery on dominant hand	0.789 (0.481-1.295)	.348
Age	0.954 (0.924-0.986)	.005
Height by group	2.198 (1.211-3.991)	.010
Height measured in centimeters	1.038 (1.015-1.062)	.001
BMI	0.985 (0.951-1.020)	.395
Sex	0.473 (0.289-0.774)	.003
Preoperative SST score	1.118 (1.008-1.24)	.035
Preoperative PCS score	1.043 (1.006-1.081)	.023
Preoperative MCS score	1.027 (0.999-1.056)	.062
Preoperative instability	0.937 (0.855-1.026)	.158
Preoperative SANE score	0.992 (0.982-1.003)	.153
Shoulder pain	0.759 (0.068-8.48)	.823
Nightly shoulder pain	1.307 (0.389-4.395)	.665
Narcotic use	1.078 (0.614-1.893)	.792
NSAID use	1.065 (0.558-2.035)	.849
Instability	0.777 (0.467-1.291)	.330
Mechanical symptoms	1.111 (0.583-2.119)	.749
Preoperative VAS score for function	9.630 (0.855-1.086)	.541
Preoperative VAS score for pain	1.022 (0.914-1.143)	.698
Preoperative ASES score total	1.001 (0.987-1.016)	.847
External rotation	1.004 (0.991-1.017)	.582
Active elevation	1.007 (0.999-1.016)	.101
Abduction	1.015 (1.00-1.029)	.044
Internal rotation	0.973 (0.869-1.089)	.631
Osteoarthritis	2.050 (0.740-5.676)	.167
Osteoporosis	0.383 (0.172-0.854)	.019
Thyroid disease	0.684 (0.349-1.342)	.269
Smoker	0.722 (0.270-1.931)	.516
Hypercholesterolemia	0.648 (0.392-1.069)	.089
Diabetes	0.760 (0.392-1.472)	.416
Inflammatory arthritis	1.338 (0.522-3.428)	.545

SST, Simple Shoulder Test; OR, odds ratio; CI, confidence interval; BMI, body mass index; MCS, Mental Component Summary; PCS, Physical Component Summary; SANE, Single Assessment Numeric Evaluation; NSAID, nonsteroidal anti-inflammatory drug; VAS, visual analog scale; ASES, American Shoulder and Elbow Surgeons.

An outstanding result is based on achievement of 72.1% of maximal improvement in the SST score.

of maximal improvement achieved in outcome scores. Our study found that 72.1% of maximal improvement in the SST score and 75.6% of maximal improvement in the ASES score represent thresholds by which approximately 90% of patients undergoing TSA will achieve excellent satisfaction. These thresholds were subsequently used as markers of excellent satisfaction, and preoperative factors were evaluated as predictors of achieving these thresholds.

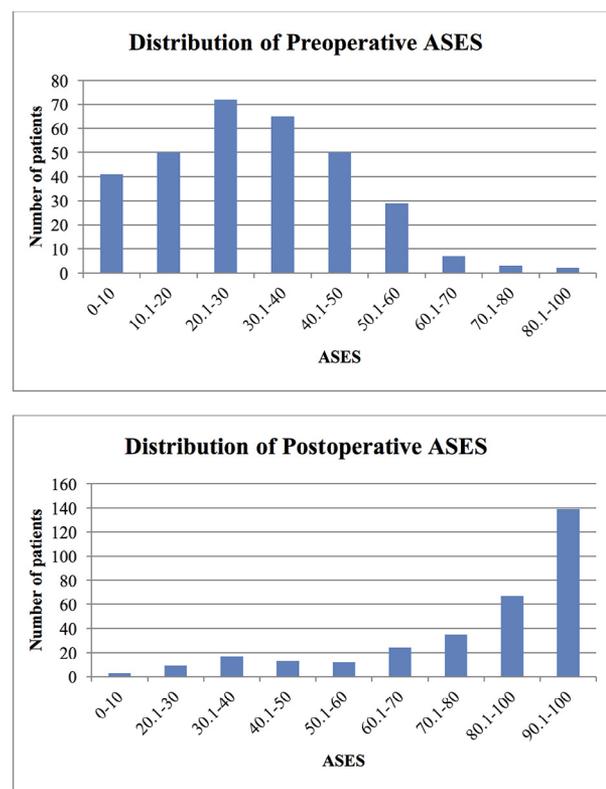
Several variables in the univariate analysis were determined to be significant predictors of an excellent result, including higher baseline SST, PCS, and MCS scores. Pre-

**Table II** Multivariate logistic regression for predictors of outstanding results according to SST score in patients undergoing total shoulder arthroplasty (based on significant results from univariate regression)

Variable	OR (95% CI)	P value
Age	0.957 (0.917-1.00)	.048
Height (measured in centimeters)	1.008 (0.968-1.05)	.699
Sex	1.510 (0.610-3.737)	.373
Preoperative SST score	1.018 (0.867-1.195)	.824
Preoperative PCS score	1.031 (0.989-1.075)	.153
Abduction	1.005 (0.984-1.025)	.659
Osteoporosis	2.005 (0.666-6.036)	.216

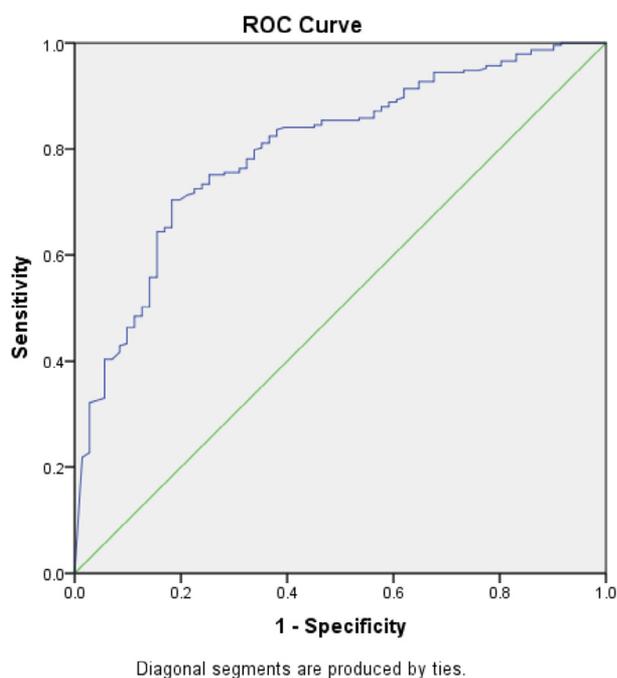
SST, Simple Shoulder Test; OR, odds ratio; CI, confidence interval; PCS, Physical Component Summary.

An outstanding result is based on achievement of 72.1% of maximal improvement in the SST score.



**Figure 4** American Shoulder and Elbow Surgeons (ASES) scores preoperatively and postoperatively.

vious studies have suggested that lower preoperative subjective functional scores were associated with better outcomes.<sup>15,25,27</sup> In contrast, our study found that patients with greater baseline functional scores have better results. Patients with greater baseline mental and emotional health were also more likely to achieve excellent results. Similar findings have been reported by Wong et al<sup>27</sup>; however, caution has been advised when using the MCS score as an exclusionary criterion for



**Figure 5** Receiver operating characteristic (ROC) curve for American Shoulder and Elbow Surgeons scores as a predictor of excellent satisfaction (area under the curve, 0.799; 95% confidence interval, 0.743-0.856;  $P < .001$ ).

shoulder arthroplasty, as the procedure does not appear to directly impact mental or emotional health.<sup>3</sup>

Despite the large number of variables analyzed, only younger age was identified as a significant independent predictor of achieving the threshold in the percentage of maximal ASES score improvement. However, with an OR of 0.957 and a confidence interval inclusive of 1, the predictive value of age on achieving an excellent result may be minimal. Previous studies analyzing patient age have not determined it to be an independent predictor of complications<sup>9</sup> or satisfaction<sup>4,16</sup> after surgery. However, concerns exist regarding shoulder arthroplasty in younger patients. Higher functional expectations and physical demands, as well as a greater number of years remaining in a patient's life, may affect implant survivability and long-term function.<sup>12</sup> Our study potentially reduces these concerns as younger patients were actually more likely to obtain an excellent result with midterm follow-up.

The strengths of this study include the large number of patients included with a minimum of 2 years' follow-up. With a sample size of over 300 patients, the fragility of the significant findings is improved. In addition, a single surgeon performed all TSA procedures; thus, in this series, surgical techniques and postoperative protocols were well standardized. Moreover, using the percentage-of-maximal improvement methodology helped to limit ceiling effects that may occur when tracking postoperative improvements in outcome measures. Finally, multivariate analyses incorporating a wide variety of preoperative factors helped control

**Table III** Univariate logistic regression of preoperative variables in patients with and without outstanding results according to ASES score undergoing anatomic total shoulder arthroplasty

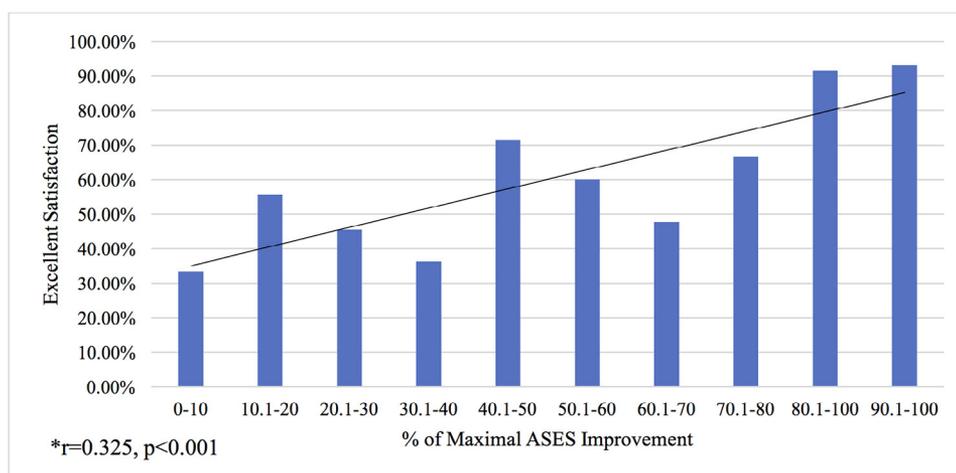
Variable	OR (95% CI)	P value
Surgery on dominant hand	0.686 (0.423-1.113)	.127
Age	0.984 (0.956-1.012)	.261
Height by group	1.946 (1.108-3.417)	.020
Height measured in centimeters	1.024 (1.002-1.046)	.033
BMI	0.998 (0.964-1.033)	.909
Sex	1.251 (0.782-1.999)	.350
Preoperative SST score	1.068 (0.971-1.175)	.176
Preoperative PCS score	1.109 (0.986-1.054)	.262
Preoperative MCS score	1.048 (1.019-1.077)	.001
Preoperative instability	0.977 (0.895-1.065)	.594
Preoperative SANE score	0.996 (0.986-1.007)	.494
Shoulder pain	1.143 (0.102-12.757)	.914
Nightly shoulder pain	1.151 (0.338-3.916)	.822
Narcotic use	0.682 (0.400-1.166)	.162
NSAID use	0.946 (0.496-1.803)	.865
Instability	0.925 (0.561-1.528)	.762
Mechanical symptoms	0.817 (0.436-1.532)	.529
Preoperative VAS score for function	0.972 (0.867-1.089)	.621
Preoperative VAS score for pain	0.975 (0.879-1.082)	.639
Preoperative ASES score total	1.006 (0.993-1.020)	.355
External rotation	0.995 (0.982-1.008)	.427
Active elevation	1.000 (0.992-1.009)	.966
Abduction	1.004 (0.991-1.016)	.579
Internal rotation	0.948 (0.852-1.055)	.326
Osteoarthritis	1.649 (0.578-4.707)	.350
Osteoporosis	1.865 (0.874-3.977)	.107
Thyroid disease	1.359 (0.722-2.558)	.341
Smoker	1.624 (0.639-4.125)	.308
Hypercholesterolemia	1.191 (0.724-1.958)	.491
Diabetes	0.989 (0.518-1.888)	.972
Inflammatory arthritis	1.076 (0.489-2.368)	.856

ASES, American Shoulder and Elbow Surgeons; OR, odds ratio; CI, confidence interval; BMI, body mass index; SST, Simple Shoulder Test; MCS, Mental Component Summary; PCS, Physical Component Summary; SANE, Single Assessment Numeric Evaluation; NSAID, nonsteroidal anti-inflammatory drug; VAS, visual analog scale.

An outstanding result is based on achievement of 75.6% of maximal improvement in the ASES score. The OR predicts the probability of achieving an outstanding result given a specific predictor variable.

for confounding variables and identify any true independent predictors.

There are several limitations to this study. The primary outcomes of the study were calculated from patient-reported outcome scores, collected together with several other patient surveys. Survey fatigue may have influenced the reproducibility of patient answers. In addition, all arthroplasty procedures were performed at a single institution by a single surgeon who performs a high volume of shoulder arthroplasty procedures. Results could potentially differ among



**Figure 6** Percentage of patients with excellent satisfaction for 10% increments in maximal American Shoulder and Elbow Surgeons (ASES) score improvement achieved.

**Table IV** Multivariate logistic regression for predictors of outstanding results according to ASES score in patients undergoing anatomic total shoulder arthroplasty (based on significant results from univariate regression)

Variable	OR (95% CI)	P value
Height (measured in centimeters)	1.019 (0.993-1.046)	.147
Preoperative PCS score	1.014 (0.980-1.049)	.423

ASES, American Shoulder and Elbow Surgeons; OR, odds ratio; CI, confidence interval; PCS, Physical Component Summary.

An outstanding result is based on achievement of 75.6% of maximal improvement in the ASES score.

different patient populations. Finally, variability likely exists as to what defines an excellent outcome for each patient. Thus, questions in the SST and ASES surveys may not best represent what is important to an individual patient. Nonetheless, the significant correlations observed suggest that the percentage of maximal improvement achieved in both the ASES and SST scores can be used to predict excellent patient satisfaction after shoulder arthroplasty.

## Conclusion

Patients achieving 72.1% of maximal SST score improvement or 75.6% of maximal ASES score improvement can be expected to achieve excellent satisfaction almost 90% of the time, whereas patients who do not achieve these thresholds only achieve excellent satisfaction about 50% of the time. Further studies might consider these thresholds when defining optimal results in patients undergoing anatomic TSA. Moderate correlations exist between the percentage of maximal SST and ASES score improvement achieved and excellent satisfaction. This suggests that a higher percentage of maximal SST and ASES scores

achieved results in higher rates of excellent satisfaction. No preoperative factors except for younger age were identified as independent predictors of achieving the established thresholds.

## Disclaimer

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