# The Prognosis for Improvement in Comfort and Function After the Ream-and-Run Arthroplasty for Glenohumeral Arthritis

## An Analysis of 176 Consecutive Cases

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**Background:** Knowledge of the factors affecting the prognosis for improvement in function and comfort with time after shoulder arthroplasty is important to clinical decision-making. This study sought to identify some of these factors in 176 consecutive patients undergoing the ream-and-run procedure.

**Methods:** The time course for improvement in patient function and comfort was determined for the entire group as well as for subsets by sex, age, diagnosis, preoperative function, and surgery date. Patients having repeat surgery were analyzed in detail.

**Results:** Shoulder comfort and function increased progressively after the ream-and-run procedure, reaching a steady state by approximately twenty months. The shoulders in 124 patients with at least two years of follow-up were improved by a minimal clinically important difference. The shoulders in sixteen patients with at least two years of follow-up were not improved by the minimal clinically important difference. Twenty-two patients had repeat procedures, but only seven had revision to a total shoulder arthroplasty. Fourteen patients did not have either a known revision arthroplasty or two years of follow-up. The best prognosis was for male patients over the age of sixty years, with primary osteoarthritis, no prior surgical procedures, a preoperative score on the Simple Shoulder Test of ≥5 points, and surgery after 2004. Repeat surgical procedures were more common in patients who had a greater number of surgical procedures before the ream-and-run surgery.

**Conclusions:** This study is unique in that it characterizes the factors affecting the time course for improvement in shoulder comfort and function after a ream-and-run procedure. Improvement occurs after this procedure for at least 1.5 years. This procedure appears to be best suited for an older male patient with reasonable preoperative shoulder function without prior shoulder surgery.

**Level of Evidence:** Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

Patients with glenohumeral arthritis considering reconstructive shoulder surgery are interested in their prognosis for improvement in comfort and function as time progresses after their procedure. A literature review revealed only a few studies describing the typical functional improvement in relation to the time elapsed after shoulder arthroplasty[1-4]. Some authors have investigated factors associated with better average results after shoulder joint replacement, such as the absence of glenoid erosion, absence of prior surgery, fewer comorbidities, better scores on the Short Form-36 (SF-36) questionnaire, better preoperative scores on the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, male sex,

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advanced age, intact rotator cuff, and a diagnosis of osteonecrosis or degenerative joint disease[5-11]. However, none of the prior studies explored the effect of these factors on the prognosis for functional improvement in relation to the time after shoulder arthroplasty.

The ream-and-run procedure is an arthroplasty method that avoids the risks of wear and loosening associated with a polyethylene glenoid component[12] and allows the potential for activities in excess of those recommended for total shoulder arthroplasty[13]. The goal of this investigation was to characterize the prognosis for improvement in shoulder comfort and function over time in a consecutive series of patients having the ream-and-run operation as well as the preoperative, intraoperative, and postoperative factors that affect the prognosis for this course of recovery. In addition, this study sought to identify the risk factors for repeat surgery after the initial shoulder arthroplasty.

## Materials and Methods

### Participants

In this retrospective cohort study, 176 patients who had the ream-and-run procedure as treatment for glenohumeral arthritis between September 1, 2000, and September 1, 2008, were included. The ream-and-run procedure was selected for each individual with use of shared surgeon-patient decision making after a thorough discussion of the risks and the alternatives, including nonoperative management, hemiarthroplasty alone, and total shoulder arthroplasty. The surgical technique[2,4,14] included a standard approach and humeral preparation. The glenoid was spherically reamed to a diameter 2 mm larger than the diameter of the prosthetic humeral head. Rather than attempting to normalize glenoid version, the reamer was oriented to remove a minimal amount of glenoid bone while fashioning a single smooth concavity. The prosthetic humeral head height was selected to allow 40° of external rotation with the subscapularis approximated, ≥150° of flexion, 50% posterior translation on drawer testing, and 60° of internal rotation with the arm abducted to 90°. Rotator interval plication was used, if necessary, to control excessive posterior subluxation. Impaction autografting of the humeral medullary canal with bone from the resected head was used to achieve a secure press fit of the humeral stem without excessive broaching. The final humeral prosthesis (Global Advantage; DePuy Orthopaedics, Johnson & Johnson, Warsaw, Indiana) was inserted with attention to achieving proper centering of the head in the reamed glenoid. The subscapularis tendon was repaired to bone with six number-2 nonabsorbable sutures placed through the lesser tuberosity. The patients were discharged once they achieved ≥150° of assisted flexion. The most commonly used humeral component had a 12-mm stem and a 52-mm head with a height of 18 mm. The most common glenoid reamer diameter was 54 mm. Rotator interval plication was used to control posterior translation in 15% of the shoulders. No rotator cuff surgery was indicated or performed as no full-thickness rotator cuff tears were identified at the time of surgery. Five percent of the patients had biceps tenotomy or tenodesis because of fraying of the biceps tendon.

Assisted shoulder flexion was started immediately after surgery. The patients were discharged from the hospital once they achieved ≥150° of assisted flexion. For the first six weeks, the rehabilitation focused on maintaining assisted flexion of 150°. At six weeks, gentle flexion strengthening was started, beginning with the two-hand supine press exercise.

For each patient, the medical record was reviewed to determine demographics, diagnosis, prior surgery, comorbidities, insurance coverage, marital status, date of surgery, the rehabilitation protocol, and patient-oriented outcome measures obtained at return visits, by mail, or by e-mail. We did not find that computed tomography (CT) scans before routine arthroplasty were worth the cost or radiation exposure to the patient. Thus, standardized preoperative axillary radiographs were used to evaluate the glenoid for evidence of retroversion or biconcavity and the anteroposterior relationship of the humeral head to the glenoid center (see Appendix). Operative reports were reviewed for details of the procedure and for associated pathology identified at the time of surgery. Our Human Subjects Review Committee approved this investigation.

### Outcome Measures

Consistent with the position of the American Academy of Orthopaedic Surgeons' (AAOS) Guideline and Evidence Report on "The Treatment of Glenohumeral Joint Osteoarthritis,"[15] we based our study on patient-oriented outcomes rather than on what the AAOS report refers to as "surrogate outcome measures"; i.e., physical signs or radiographic results "used as substitutes for a clinically meaningful end point that measures directly how a patient feels, functions or survives." Before surgery, all patients assessed their comfort and function with use of the Simple Shoulder Test (SST)[16-18]. Patients completed the SST at varying follow-up times, either during return clinic visits or in response to periodic mailings with the goal of obtaining annual follow-up data on each patient. Missing data resulted when patients neither returned for follow-up nor completed the mailed forms. The ability to capture the patients' self-assessed comfort and function via mail was of particular value in this group of patients who lived an average distance of >500 miles from our center. The investigation included all follow-up data in the medical record through September 1, 2010, including the dates and types of any known repeat surgical procedures.

The minimal clinically important difference (MCID) in outcome measures for the treatment of shoulder disorders has been variously defined, ranging from a 10% improvement to a 30% improvement (see Appendix)[16,19-21]. Tashjian et al.[16] suggested that a 2-point change in the SST score was the MCID for patients with rotator cuff disease. Roy et al.[18] proposed that the MCID in the SST score for patients undergoing shoulder arthroplasty was 3 points. These approaches are limited, however, by the ceiling effect. For example, a patient with a preoperative SST score of 10 could not improve by 3 points because 12 points is the maximal score possible. Furthermore, it is obvious that a 3-point improvement from an SST score of 0 to 3 points (25% of the maximal possible improvement) may not be the same as a 3-point improvement from an SST of 9 to 12 points (100% of the maximal possible improvement).

We utilized an alternative approach in evaluating the benefit of shoulder arthroplasty by determining the percentage of the total possible improvement realized by the patient. In this calculation, the improvement realized by the patient is divided by the total possible improvement for the patient (i.e., the difference between the maximal possible score on the SST [12 points] and the preoperative score). Thus, the percentage of the total possible improvement is calculated as:

$$\frac{(\text{SST total score at the time of follow-up} - \text{SST total score before surgery}) \times 100\%}{(12 \text{ points} - \text{SST total score before surgery})}$$

For purposes of this analysis, we defined the MCID as an improvement of 30% of the total improvement possible[22]. Thirty percent is the highest percent improvement required for an MCID in the shoulder literature[16,19-21]. It is of interest that since the average preoperative SST score was 4 points, the average maximal possible improvement was 8 points. Thirty percent of this value would be 2.4 points, a value that lies between the values separately proposed by Roy et al.[18] and Tashjian et al.[16]. The value of the method selected for our analysis lies in the fact that it avoids the ceiling effect, and the MCID is normalized by the maximal possible improvement for each patient, rather than consisting of a fixed value applied to all patients irrespective of their maximal possible improvement.

### Statistical Analysis

Four possible outcome states were considered in this study: (1) a follow-up interval of at least two years with improvement greater than or equal to the MCID, (2) at least two years of follow-up with improvement less than the MCID, (3) less than two years of follow-up without known repeat surgery, and

**TABLE I Baseline Characteristics of 176 Patients by Outcome After Ream-and-Run Shoulder Surgery***

| Baseline Characteristics | Change of ≥30% in SST Score | Change of <30% in SST Score | Reoperation | Follow-up Data Missing |
|---|---|---|---|---|
| No. of patients | 124 | 16 | 22 | 14 |
| Age† *(yr)* | 56.8 (9.8) | 58.3 (7.7) | 54.6 (7.6) | 53.1 (11.6) |
| Male patients | 118 (95%) | 13 (81%)‡ | 19 (86%) | 11 (79%)‡ |
| Surgery on dominant side *(no. of patients)* | 56 (45%) | 7 (44%) | 9 (41%) | 8 (57%) |
| Patients who were married | 97 (78%) | 12 (75%) | 21 (95%) | 10 (71%) |
| Distance from center† *(miles)* | 557 (836) | 498 (828) | 617 (787) | 718 (853) |
| Insurance *(no. of patients)* | | | | |
| Commercial | 87 (70%) | 9 (56%) | 16 (72%) | 12 (86%) |
| Medicare or Medicaid | 27 (22%) | 4 (25%) | 3 (14%) | 1 (7%) |
| Labor and industries | 7 (6%) | 3 (19%) | 2 (9%) | 0 (0) |
| Self-insured or not insured | 3 (2%) | 0 (0) | 1 (5%) | 1 (7%) |
| No. of comorbidities† | 1.4 (1.4) | 2.3 (1.7) | 1.7 (1.7) | 1.4 (1.2) |
| Smokers | 6 (5%) | 0 (0) | 0 (0) | 1 (7%) |
| Previous operations *(no. of patients)* | | | | |
| 0 | 63 (51%) | 7 (44%) | 6 (27%) | 3 (21%) |
| 1 | 37 (30%) | 4 (25%) | 7 (32%) | 8 (57%) |
| 2 | 17 (14%) | 4 (25%) | 3 (14%) | 2 (14%) |
| 3 | 7 (6%) | 1 (6%) | 6 (27%)‡ | 1 (7%) |
| Baseline score on Simple Shoulder Test† *(points)* | 4.6 (2.5) | 5.0 (3.0) | 4.2 (2.5) | 3.0 (2.3)‡ |
| Follow-up examinations | | | | |
| No. of visits§ | 4 (3-6) | 4 (3-6) | 2 (1-3) | 1 (0-2)# |
| Time to last examination† *(yr)* | 4.5 (1.9) | 4.4 (2.1) | 1.3 (1.4)# | 0.7 (0.8)# |
| Time to last examination§ *(yr)* | 4.1 (3.1-5.5) | 4.0 (2.5-5.6) | 0.7 (0.1-2.3) | 0.3 (0-1.7)# |

*P values were calculated with use of a likelihood ratio test from a logistic regression model comparing baseline characteristics of each negative outcome category with patients who had a change of ≥30% in the score on the Simple Shoulder Test (SST). †The values are given as the mean, with the standard deviation in parentheses. ‡Compared with patients who had a change of ≥30% in the SST score, the difference was significant ($p < 0.05$). §The values are given as the median, with the 25% to 75% interquartile ranges in parentheses. #Compared with patients who had a change of ≥30% in the SST score, the difference was significant ($p < 0.01$).

(4) known repeat surgery on the shoulder. Shoulders having repeat surgery were described in detail and classified by the type of repeat surgery, including (1) subscapularis repair, (2) closed manipulation, (3) soft-tissue release, (4) repeat reaming, (5) conversion to total shoulder arthroplasty, and (6) a procedure for infection. These cases were further characterized by the reason for the repeat surgery, the time from the index arthroplasty to the repeat surgery, the surgical findings at the time of the repeat surgery, as well as the other variables used for the other outcome groups.

For each outcome state, means (and standard deviations) or medians (and interquartile ranges) were presented for continuous baseline characteristics, and frequency (percentages) were tabulated for categorical baseline characteristics. Relative to patients achieving the MCID (≥30% of the possible improvement on the SST), we used separate univariate logistic regression models to assess the likelihood (odds) of each poor outcome state for baseline characteristics and preoperative outcome measures. Likelihood ratio tests were used to determine the significance of factors evaluated as prognostic indicators of a poor outcome state.

Trends in the SST score were plotted with use of a cubic smoothing spline as a function of time after surgery for all patients. To assess the postoperative recovery and the factors affecting it, we constructed plots for the entire cohort and for various subgroups of clinical and prognostic interest: sex, age, diagnosis, year of surgery, and preoperative SST score. Separate linear mixed-effects models[23] were utilized to estimate and make inference on the following quantities for each subgroup: (1) the rate of improvement (change) in SST scores during the first two years of postoperative recovery, (2) average SST scores at two years after surgery, and (3) the durability of SST scores (slope) beyond two years postoperatively. In order to estimate the best fitting "two-line" curve (i.e., the change before and then after the two-year mark) for each prognostic factor, we adjusted the linear mixed-effects model for an interaction term between the prognostic factor and follow-up time (before two years) and a separate interaction term between the prognostic factor and follow-up time (after two years). Inference on differences between levels of each prognostic factor was made with use of a Wald test[24]. P values are two-sided and are not adjusted for multiple testing.

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## Results

Between September 1, 2000, and September 1, 2008, 176 patients had ream-and-run procedures. For the patients who had bilateral procedures, only the first shoulder was

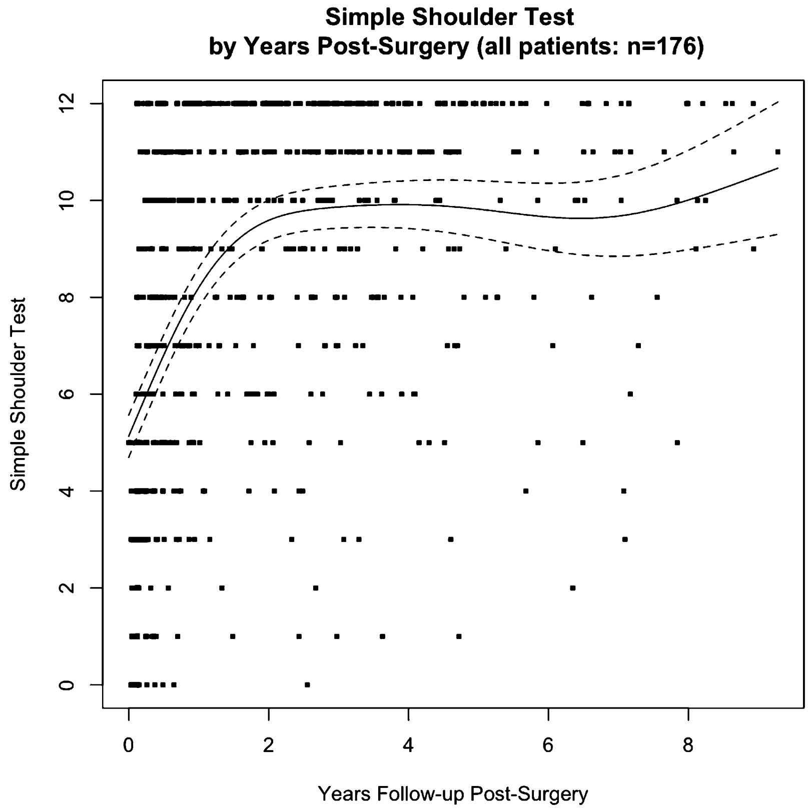


Fig. 1

Mean Simple Shoulder Test (SST) scores (and 95% confidence intervals) by follow-up time for 176 patients who underwent a ream-and-run procedure as treatment for glenohumeral arthritis.

included in this analysis (Table I). Of the 176 patients, definitive follow-up was available for 162 (92%): 140 patients had at least two years of follow-up and twenty-two had repeat surgery (see Appendix). Fourteen patients were lost to follow-up.

Of the unrevised shoulders with at least two years of follow-up, 124 reached at least the MCID in comparison with their baseline SST scores and sixteen did not. Patient characteristics of the four outcome groups are demonstrated in Table I. The percentage of females in the group that did not reach the MCID (19%) and the group with less than two years of follow-up (21%) was significantly higher than that in the group that reached the MCID (5%) ($p < 0.05$). The distances that patients traveled from their homes to our center were substantial, averaging 572 miles, but were not significantly different among the four groups. The prevalence of other factors, such as marital status, insurance coverage, comorbidities, and smoking were not significantly different among the groups. Patients with less than two years of follow-up had significantly lower preoperative SST scores than did the other groups ($p < 0.05$). The mean and median durations of follow-up were the same for the patients who achieved the MCID with regard to improvement in their SST scores and those who did not achieve the MCID.

The average prognosis for improvement in the SST score as a function of time after surgery is shown in Figure 1. The average preoperative SST score for all 176 patients was $4 \pm 2.5$ points. On average, the MCID of 2.4 points (30% of the difference between 12 and 4.5 points) was achieved at six months. Average function increased progressively to a stable level of function, an SST score of 10 points, at two years after surgery.

The effect of different patient characteristics on the prognosis for improvement in the SST score with time is shown in Figure 2 and Table II. Men and older patients had more improvement in shoulder function than did women and younger patients. Patients with degenerative joint disease improved more rapidly than patients with other diagnoses. Patients who had had three or more surgical procedures before their ream-and-run procedure had a poorer prognosis than those with fewer procedures. Patients with lower levels of function before surgery improved at a higher rate after surgery compared with those with higher levels of preoperative function. Finally, the prognosis for shoulders that had a ream-and-run procedure after 2004 was that they would have a faster and more complete rate of functional improvement than those that had this procedure in earlier years.

We were particularly interested in the effect of preoperative glenoid morphology and glenohumeral relationship on the result. These results are summarized in Table III. There were no significant differences in glenoid morphology among the outcome groups. None of our patients experienced problems with posterior glenohumeral instability despite the presence of retroversion, biconcavity, and posterior humeral displacement in some of the preoperative radiographs.

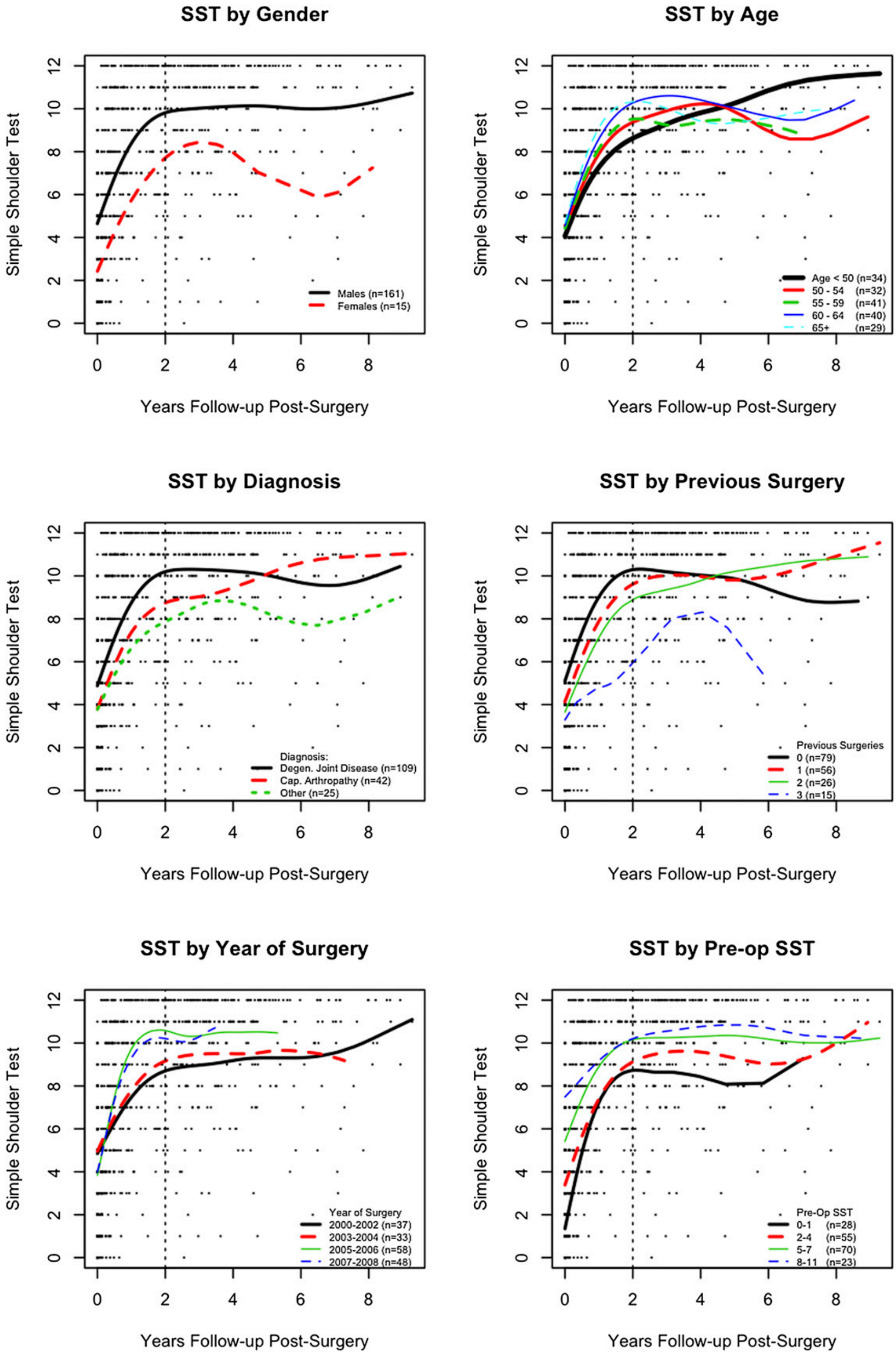


Fig. 2

Mean Simple Shoulder Test (SST) scores by follow-up time stratified by baseline prognostic characteristics.

**TABLE II Rate of Change in Scores on the Simple Shoulder Test from the Date of Surgery Through Two Years, the Scores at Two Years, and the Change in Scores More Than Two Years After Surgery**

| | Rate of Improvement in SST Score at 2 Years* | | SST Score at 2 Years* | | Durability of Scores (>2 Years)* | |
|---|---|---|---|---|---|---|
| | Mean Change (95% CI) *(points)* | P Value† | Mean Score (95% CI) *(points)* | P Value† | Mean Change in Score (95% CI) *(points)* | P Value† |
| Sex | | 0.49 | | 0.03 | | 0.11 |
| Male | 2.7 (2.5 to 3.0) | | 10.3 (9.9 to 10.8) | | –0.2 (–0.3 to 0.0) | |
| Female | 3.0 (2.2 to 3.9) | | 8.5 (6.9 -10.0) | | –0.6 (–1.2 to –0.1) | |
| Age *(yr)* | | 0.16 | | 0.01 | | 0.09 |
| <50 | 2.4 (1.8 to 3.0) | | 9.0 (7.9 to 10.0) | | 0.2 (–0.2 to 0.5) | |
| 50 to 54 | 2.6 (2.0 to 3.2) | | 9.9 (8.9 to 11.0) | | –0.2 (–0.5 to 0.2) | |
| 55 to 59 | 2.6 (2.1 to 3.2) | | 9.8 (8.8 to 10.8) | | –0.2 (–0.6 to 0.2) | |
| 60 to 64 | 3.3 (2.8 to 3.7) | | 11.3 (10.4 to 12.0) | | –0.4 (–0.7 to –0.1) | |
| ≥65 | 2.8 (2.2 to 3.3) | | 10.7 (9.6 to 11.8) | | –0.4 (–0.8 to 0.0) | |
| Initial diagnosis | | 0.40 | | 0.002 | | 0.30 |
| Degenerative joint disease | 2.7 (2.3 to 3.0) | | 10.7 (10.1 to 11.2) | | –0.2 (–0.4 to –0.0) | |
| Capsulorrhaphy arthropathy | 2.3 (1.6 to 3.0) | | 9.0 (8.0 to 10.0) | | 0.1 (–0.2 to 0.5) | |
| Other | 2.1 (1.2 to 3.1) | | 8.7 (7.3 to 10.0) | | –0.1 (–0.6 to 0.3) | |
| No. of previous surgeries | | 0.61 | | <0.001 | | 0.58 |
| 0 | 2.6 (2.2 to 3.0) | | 10.8 (10.2 to 11.5) | | –0.4 (–0.6 to –0.1) | |
| 1 | 2.6 (2.1 to 3.2) | | 10.0 (9.2 to 10.9) | | 0.1 (–0.3 to 0.2) | |
| 2 | 2.7 (1.9 to 3.4) | | 9.5 (8.2 to 10.7) | | 0.1 (–0.3 to 0.4) | |
| 3 | 1.6 (0.1 to 3.1) | | 6.5 (4.7 to 8.4) | | 0.1 (–1.0 to 1.3) | |
| Year of surgery | | <0.001 | | <0.001 | | <0.001 |
| 2000 to 2002 | 2.0 (1.5 to 2.5) | | 9.0 (8.1 to 9.8) | | 0.0 (–0.2 to 0.2) | |
| 2003 to 2004 | 2.4 (1.9 to 3.0) | | 9.8 (8.8 to 10.7) | | –0.1 (–0.4 to 0.2) | |
| 2005 to 2006 | 3.5 (3.0 to 4.0) | | 11.5 (10.5 to 12.0) | | –0.7 (–1.2 to –0.2) | |
| 2007 to 2008 | 3.3 (2.7 to 3.8) | | 11.0 (10.0 to 12.0) | | –0.8 (–2.1 to 0.5) | |
| Preop. SST score *(points)* | | <0.001 | | 0.20 | | 0.001 |
| 0 to 1 | 4.0 (3.3 to 4.7) | | 9.7 (8.7 to 10.8) | | –0.6 (–1.4 to 0.1) | |
| 2 to 4 | 3.1 (2.7 to 3.6) | | 9.9 (9.2 to 10.6) | | –0.1 (–0.4 to 0.3) | |
| 5 to 7 | 2.5 (2.1 to 2.9) | | 10.7 (10.1 to 11.3) | | –0.1 (–0.5 to 0.2) | |
| 8 to 11 | 1.5 (0.8 to 2.2) | | 10.6 (9.6 to 11.6) | | 0.0 (–0.5 to 0.5) | |

*The mean Simple Shoulder Test (SST) scores and 95% confidence interval (95% CI) and rates of SST change were estimated with use of a linear mixed-effects model, where two lines (e.g., ''hockey stick'') are simultaneously fitted to each study participant's SST scores and the bend is fixed at two years. This analytic approach utilizes all available follow-up data for all study participants to estimate the overall trends in SST scores after surgery, regardless of duration of follow-up or revision surgery. †P values were generated with use of a Wald test of whether mean SST scores or rates of change are different between the levels of the prognostic covariates.

None of these patients had full-thickness rotator cuff tears, and none had any rotator cuff surgery at the time of the ream-and-run procedure. Five percent of the patients had biceps tenotomy or tenodesis because of fraying of the tendon. The outcome did not correlate with the dimensions of the prosthesis selected, the use of rotator cuff interval plication, or biceps surgery.

Twenty-two patients had repeat surgery (see Appendix). It is of interest that six of the twenty-two patients who had repeat surgery had three or more prior surgical procedures, a higher percentage than in the other outcome groups. Four repeat surgical procedures were to repair tears of the upper subscapularis tendon reattachment to bone. Two patients had shoulder manipulations because of difficulty with their early rehabilitation. Four had open procedures for stiffness. Three had persistent pain and stiffness but chose repeat glenoid reaming rather than to have conversion to a total shoulder arthroplasty. Six chose to have revision to a conventional total shoulder arthroplasty because of pain and stiffness. One required revision to a reverse total shoulder arthroplasty because of intractable instability. Two were revised at fifteen and thirty-three months after surgery with a primary humeral exchange because of infection, at least one of which resulted from infection at a remote site. Of the twenty-two repeat surgical

**TABLE III Glenoid Morphology for Each of the Four Outcome Groups**

| | Improvement of ≥MCID* | Improvement of <MCID* | Repeat Procedure | Inadequate Follow-up |
|---|---|---|---|---|
| Posterior subluxation† | 60% ± 11% | 65% ± 10% | 60% ± 13% | 60% ± 10% |
| Retroversion‡ | 75%, 11%, 11%, 3% | 60%, 13%, 20%, 7% | 85%, 5%,5%, 5% | 69%, 0%, 31%, 0% |
| Biconcave§ | 23% | 38% | 14% | 21% |

*MCID = minimal clinically important difference. †Position of middle of humeral contact in relation to the anteroposterior dimension of the glenoid on the axillary view. The values are given as the mean and the standard deviation. ‡Degree of retroversion on axillary radiograph according to percentage that had none or minimal, mild, moderate, severe. §Two distinct concavities on the axillary radiograph.

procedures, fifteen had not had a revision of the glenoid side of the arthroplasty to a polyethylene prosthesis; only 4% of the 176 patients who had ream-and-run procedure were known to have had revision to a total shoulder arthroplasty.

## Discussion

This study provides evidence on the factors affecting the prognosis for improvement in self-assessed shoulder comfort and function with time after the ream-and-run procedure. On average, the comfort and function increased progressively, reaching a steady state by approximately twenty months. Patient age, sex, diagnosis, preoperative SST score, and number of prior surgical procedures affected the prognosis for recovery as a function of time after the procedure. The prognosis for improvement in comfort and function was also better for patients who had the surgery in the later years of the study. We were not certain whether this observation is related to (1) better patient selection, (2) improvements in surgical technique, (3) refinements in the aftercare of patients who had this procedure, or (4) a combination of these factors.

It is of note that the prognosis for improvement after the ream-and-run procedure in the present study was similar to that reported previously for total shoulder arthroplasty[1,3]. The value of the use of a metric based on patient self-assessment, like the SST, is that reliable comparisons can be carried out among centers without concern about differences in physical examination or radiographic technique, examiner bias, or ability to travel for follow-up. The value of focusing on the prognosis by diagnosis is also that reliable comparisons can be carried out among centers. Both of these points are demonstrated by comparing the results for patients selected for the ream-and-run procedure in the present study with those selected for total shoulder arthroplasty at another center, where the average result was an SST score of 10.3 points for patients with primary glenohumeral degenerative joint disease[25].

While some consider the total shoulder arthroplasty the gold-standard treatment for glenohumeral arthritis, concern about glenoid component wear and loosening continues to be expressed in the current orthopaedic literature[12,26-43]. Furthermore, recent studies have demonstrated that the results of total shoulder arthroplasty in young and active patients are poorer than those in older patients[11,44-46]. As we previously pointed out, these studies may have an inherent bias because of the more complex forms of arthritis seen in younger patients[47]. In view of these concerns about the prognosis for total shoulder arthroplasty, surgeons have explored approaches to the glenoid side of the arthroplasty other than a polyethylene component, especially in more active patients who will expose their prosthetic joints to higher levels of use (see Appendix)[17,48-63]. However, the authors of the AAOS guidelines did not find evidence on which to base a recommendation "for or against open débridement and/or nonprosthetic or biologic interposition arthroplasty in patients with GH OA [glenohumeral joint osteoarthritis]."[15] These treatments include allograft, biologic and interpositional grafts, and autograft. In contrast to these treatments, the procedure used in the current study, the ream-and-run arthroplasty, is a method of managing the glenoid side of the arthritic glenohumeral joint by reaming the glenoid bone surface to a concentric concavity without either a polyethylene glenoid component or an interposing of biologic or synthetic material between the prosthetic humeral head and the glenoid bone surface[2,4,14,64-68].

Our investigation demonstrates a practical and generalizable method by which the prognosis for recovery over time and the factors affecting this prognosis can be characterized for any type of shoulder arthroplasty. Also, it provides data from a substantial number of patients, revealing some of the factors affecting the prognosis for improvement in comfort and function with time after a ream-and-run procedure.

The results of this study should be viewed in light of certain limitations. First, the patients who are offered and elect this procedure are typically highly motivated, healthy, and desirous of levels of function in excess of what is usually advised after a total shoulder replacement[13]. As such, they have high expectations for recovery and are not typical of the population of individuals who have traditional total shoulder arthroplasty. Second, these patients live an average distance of >500 miles from our center so that periodic, in-person follow-up with standardized physical examination and radiographs was not practical for the majority; as a result, we relied on the patient's assessment of his or her own shoulder comfort and function consistent with the principles published in the recent AAOS guideline[15]. Third, the procedures were all performed by one of two surgeons at our institution experienced in this technique; thus, the results may not be representative of other practices. Fourth, although we try to stay in close contact with each of our patients, it is possible that repeat procedures were performed elsewhere without our knowledge. Fifth, the numbers of patients for whom data were available were not the same at each time point after surgery. Finally, many of these patients were able to achieve extraordinary degrees of function—including the ability to chop wood, win major racquet sport championships, return to beat police work, engage in white-water boating, practice martial arts (including black belt karate), and participate in heavy weight-lifting. We were not able to capture systematically these high-end achievements in this study.

This study indicates that the ream-and-run procedure can be highly effective in older patients and that younger patients may have less optimal outcomes. At this point, no prospective study, to our knowledge, has compared the ream-and-run procedure with total shoulder arthroplasty. The type of glenoid had no significant effect on the outcome, and our patients had no problems with posterior glenohumeral instability although a substantial number of the glenoids were posteriorly eroded and the humeral head was displaced into the posterior aspect of a biconcavity.

Because of the occurrence of some postoperative subscapularis tears, we modified our approach to be particularly careful with the reattachment of the tendon to bone and to advise patients to avoid activities that would stress this reattachment for the first six weeks. Finally, the problems observed with stiffness in these patients, many of whom did their own rehabilitation, led us to refer each patient to a therapist with the single purpose of ensuring that at least 150° of flexion was maintained for the first six weeks after surgery.

In conclusion, this study is the first, to our knowledge, to investigate the factors affecting the time course for improvement in shoulder function with time after any type of shoulder arthroplasty. These prognostic findings are in a form that can be easily understood by patients considering this procedure and would easily enable comparison with other approaches to glenohumeral arthroplasty. In this study, the patients with the best prognosis for improvement with ream-and-run shoulder arthroplasty were men over sixty years old who had primary degenerative joint disease, no previous surgical procedure on the shoulder, a preoperative SST score of ≥5 points, and had the surgery after 2004.

## Appendix

eA Figures showing normal and abnormal glenoid morphology and a table showing data on the patients who had repeat surgery are available with the online version of this article as a data supplement at jbjs.org. ■

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