**A commentary by Samer S. Hasan, MD, PhD,** is linked to the online version of this article at jbjs.org.

# Clinical and Radiographic Outcomes of the Ream-and-Run Procedure for Primary Glenohumeral Arthritis

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**Background:** The ream-and-run procedure can provide improvement in shoulder function and comfort for selected patients with primary glenohumeral arthritis who wish to avoid a prosthetic glenoid component. The purpose of this study was to evaluate factors associated with medialization of the humeral head after this procedure as well as the relationship of medialization to the clinical outcome.

**Methods:** We collected patient, shoulder, and procedure characteristics along with Simple Shoulder Test (SST) scores before surgery and at the time of follow-up. Medialization was determined by comparing the position of the humeral head prosthesis in relation to the scapula on postoperative baseline radiographs made within 6 weeks after surgery with that on comparable follow-up radiographs made ≥18 months after surgery.

**Results:** Two-year clinical outcomes were available for 101 patients (95% were male). Comparable radiographs at postoperative baseline and follow-up evaluations were available for 50 shoulders. For all patients, the mean SST score (and standard deviation) increased from 4.9 ± 2.8 preoperatively to 10.3 ± 2.4 at the latest follow-up ($p < 0.001$). Significant clinical improvement was observed for glenoid types A2 and B2. Shoulders with a type-A2 glenoid morphology, with larger preoperative scapular body-glenoid angles, and with lower preoperative SST scores, were associated with the greatest clinical improvement. Clinical outcome was not significantly associated with the amount of medialization.

**Conclusions:** The ream-and-run procedure can be an effective treatment for advanced primary glenohumeral osteoarthritis in active patients. Further study will be necessary to determine whether medialization affects the clinical outcome with follow-up of >2 years.

**Level of Evidence:** Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

The ream-and-run procedure is a glenohumeral arthroplasty that avoids the potential limitations and risks associated with a prosthetic glenoid component[1,2] and provides the patient with the opportunity for a level of activity beyond that recommended for a total shoulder arthroplasty[3,4]. The distinguishing element of the ream-and-run procedure is the nonprosthetic glenoid arthroplasty that is accomplished by the conservative spherical contouring of the osseous glenoid surface to optimize both glenohumeral stability and the distribution of load applied by the humeral prosthesis. In selected patients with glenohumeral arthritis, the ream-and-run procedure has provided significant improvement in shoulder function and comfort[5-11]. A prior analysis of 176 ream-and-run surgeries showed a mean Simple Shoulder Test (SST) score of 10 at a minimum follow-up of 2 years[5]. The best scores at the time of follow-up were seen in men who were

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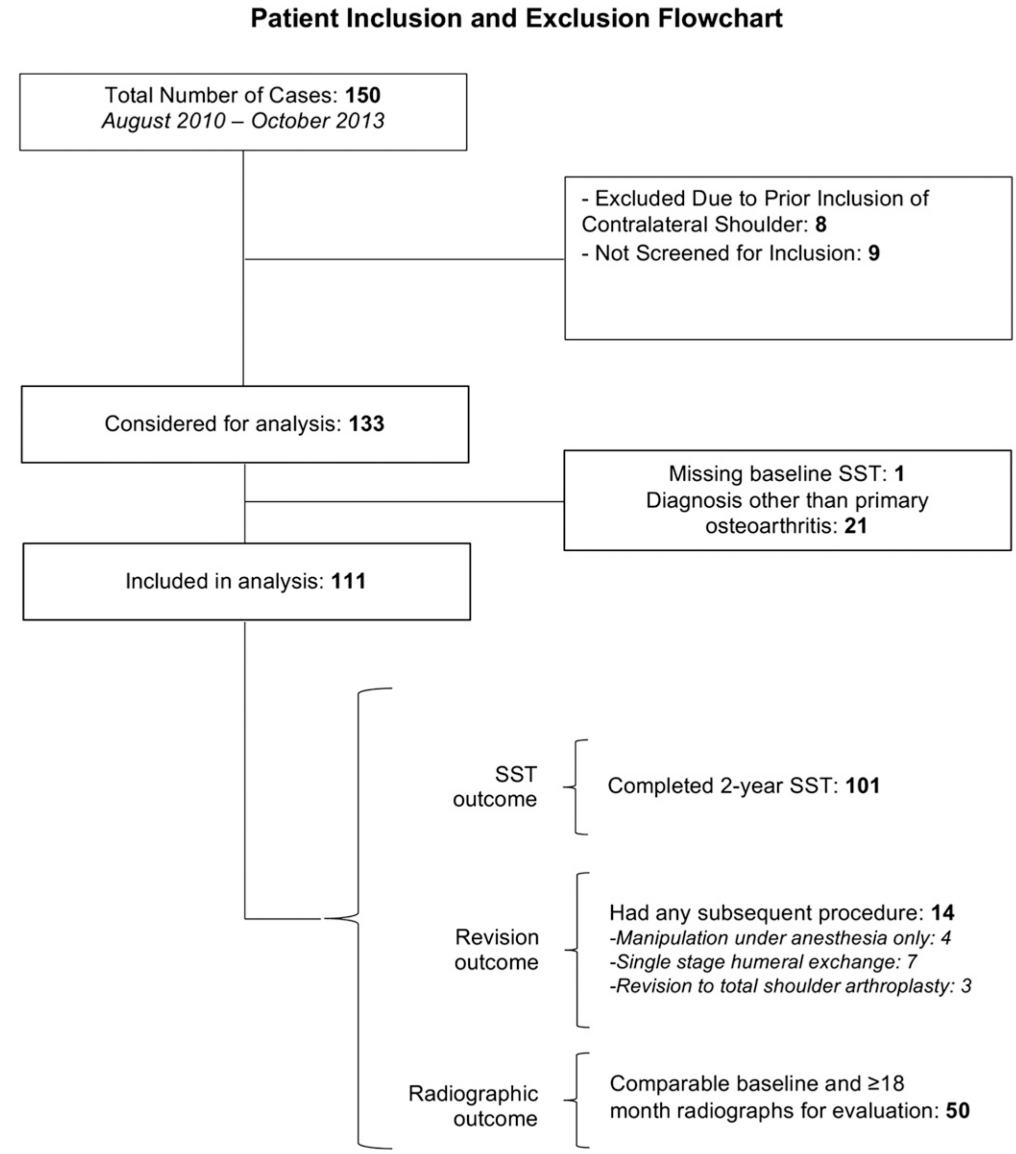


Fig. 1
Flowchart demonstrating patient inclusion in the study.

>60 years old with primary degenerative joint disease, no prior procedures, a preoperative SST score of ≥5 points, and surgery dates after 2004[5]. Radiographic outcomes were not reported in that series.

The purpose of this study was to answer the following 2 questions: (1) What factors were associated with the amount of medialization of the humeral head relative to the scapula after the ream-and-run procedure? (2) To what degree were the clinical outcomes after the ream-and-run procedure associated with the amount of postoperative medialization[5-18]?

## Materials and Methods

### *Study Design*

In our practice, the ream-and-run procedure is offered to highly motivated patients with failed nonoperative management of advanced glenohumeral arthritis after a detailed discussion of the pros and cons of this procedure along with those of alternative strategies, including continued nonoperative management, anatomic total shoulder arthroplasty, and reverse total shoulder arthroplasty[19-22]. Patients with inflammatory arthropathy, infection, and rotator cuff defects as well as those unwilling to commit to the requisite rigorous rehabilitation program are not offered this procedure. This study analyzed shoulders that had a ream-and-run shoulder arthroplasty between August 24, 2010, and October 22, 2013 (Fig. 1). This study was approved by our Human Subjects Review Committee (Institutional Review Board Approval #38897), and all patients gave informed consent to participate.

Preoperative radiographs (Figs. 2-A and 2-B) were made to document the glenoid type, the degree of decentering of the humeral head on the glenoid, and the glenoid-scapular body angle[23,24]. The axillary views were standardized with the arm elevated 90° in the plane of the scapula to detect functional decentering of the humeral head, which may not be observed when imaging is performed with the arm at the side[25]. In the unusual case in which the arm could not be elevated 90°, the radiograph was made with the arm in maximal elevation.

Fig. 2-A

Fig. 2-B

**Figs. 2-A through 2-D** Standardized radiographs of a shoulder with loss of radiographic joint space and a type-B2 glenoid that was managed with the ream-and-run procedure. **Fig. 2-A** Preoperative anteroposterior radiograph in the plane of the scapula showing loss of radiographic joint space. **Fig. 2-B** Preoperative axillary lateral radiograph with the arm in the functional position of 90° of elevation in the plane of the scapula, showing severe posterior decentering of the humeral head and a biconcave (type-B2) glenoid.

Fig. 2-C

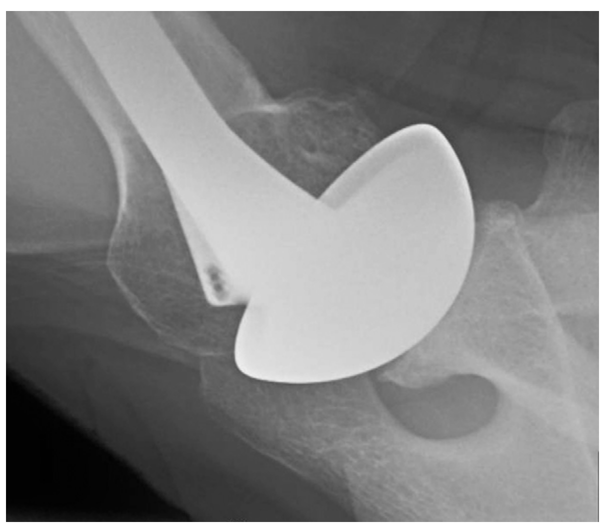

Fig. 2-D

**Figs. 2-C and 2-D** Standardized radiographs made 3 years after the ream-and-run procedure, at which time the patient was able to perform all 12 functions of the SST. **Fig. 2-C** Anteroposterior radiograph showing the impaction-grafted humeral component. **Fig. 2-D** Axillary lateral radiograph showing an anteriorly eccentric humeral head centered in the conservatively reamed glenoid concavity.

**TABLE I Descriptive Statistics for Baseline Characteristics and Outcomes**

| Characteristic | No.* | Mean and Stand. Dev. (Range) or No. (%) |
|---|---|---|
| Age† *(yr)* | 111 | 60 ± 9 (35 to 80) |
| Male | 111 | 105 (95) |
| ASA classification‡ | 111 | |
| I | | 25 (23) |
| II | | 73 (66) |
| III | | 13 (12) |
| Alcohol | 111 | 78 (70) |
| Smoking | 111 | |
| Never | | 73 (66) |
| Passive | | 4 (4) |
| Quit | | 31 (28) |
| Yes | | 3 (3) |
| Body mass index† *(kg/m²)* | 111 | 29 ± 5 (22 to 47) |
| Surgery on dominant side | 111 | 72 (65) |
| Preop. scapular body-glenoid angle† *(deg)* | 111 | 69 ± 12 (40 to 95) |
| Work-related condition | 111 | 8 (7) |
| Prior shoulder surgery | 111 | 29 (26) |
| Glenoid type | 111 | |
| A1 | | 2 (2) |
| A2 | | 42 (38) |
| B1 | | 18 (16) |
| B2 | | 49 (44) |
| Surgery year† | 111 | 2012.1 ± 1.0 (2010.6 to 2013.8) |
| Head diameter in mm | 111 | |
| 52 | | 7 (6) |
| 56 | | 104 (94) |
| Head height in mm | 111 | |
| 15 | | 4 (4) |
| 18 | | 62 (56) |
| 21 | | 42 (38) |
| Other | | 3 (3) |
| Antibiotics | 111 | |
| Cefazolin | | 50 (45) |
| Ceftriaxone | | 3 (3) |
| Clindamycin | | 7 (6) |
| Vancomycin and ceftazidime | | 1 (1) |
| Vancomycin and ceftriaxone | | 50 (45) |
| Biceps tendon condition at surgery | 111 | |
| Normal | | 98 (88) |
| Thin | | 9 (8) |
| Torn | | 4 (4) |
| Rotator interval plication | 111 | 25 (23) |
| Eccentric humeral component used | 111 | 30 (27) |
| Inferior osteophyte | 53 | 32 (60) |
| Medialization† *(mm)* | 50 | 2.4 ± 3.2 (−3.6 to 9.0) |

*continued*

**TABLE I (*continued*)**

| Characteristic | No.* | Mean and Stand. Dev. (Range) or No. (%) |
|---|---|---|
| SST† | | |
| Preop. | 111 | 4.9 ± 2.8 (0.0 to12.0) |
| 2 yr | 101 | 10.3 ± 2.4 (0.0 to 12.0) |
| Change from preop. to 2 yr | 101 | 5.4 ± 2.6 (−4.0 to 12.0) |
| Percentage of MPI†§ | 99 | 75 ± 34 (−100 to 100) |
| Repeat procedure | 111 | 14 (13) |
| Radiographic joint space present at 2 yr | 50 | 19 (38) |

*There were 111 shoulders with baseline data, 101 with minimum 2-year clinical follow-up data, and 99 with data on percentage of MPI as 2 patients had a starting SST of 12 with resultant undefined percentage of MPI. Adequate radiographs were available for evaluation of an inferior osteophyte in 53 shoulders, for evaluation of a radiographic joint space in 50 shoulders, and for evaluation of medialization change from baseline to 2 years in 50 shoulders. †The values are given as the mean and the standard deviation, with the range in parentheses. ‡ASA = American Society of Anesthesiologists. §The percentage of MPI is the percentage of the maximum possible improvement in the Simple Shoulder Test.

The surgical technique has been described previously[19,21,22]. The subscapularis tendon was detached with a peel technique and repaired using 6 number-2 nonabsorbable sutures passed through drill-holes in the lesser tuberosity. In shoulders in which the glenoid was biconcave, the ridge between the 2 concavities was removed with a burr. With emphasis on preservation of glenoid bone stock, the glenoid face was reamed to a single smooth concavity using a nubbed spherical reamer with a diameter 2 mm larger than the diameter of the humeral head prosthesis. No glenoid guidewire was used; no specific attempt was made to alter glenoid version. A stemmed humeral prosthesis (Global Advantage; DePuy Synthes, Johnson & Johnson) was secured using impaction autografting with bone harvested from the resected humeral head[26]. A humeral head with a diameter of curvature of 56 mm was used in the majority of cases to maximize stability and joint contact area. Intraoperative posterior humeral decentering, if present, was managed using a 4-mm anteriorly eccentric humeral component without or with rotator interval plication (Figs. 2-C and 2-D)[24].

### Demographic and Clinical Variables

Patient and shoulder characteristics were documented preoperatively, intraoperatively, and postoperatively (Table I). Clinical outcome was expressed as the change in the follow-up SST score from the preoperative SST score (ΔSST) as well as by the improvement in the SST score expressed as the percent of the maximum possible improvement (% MPI) ([follow-up SST score – preoperative SST score]/[12 – preoperative SST score])[5,27-29].

### Radiographic Variables

Assessment of the amount of medialization occurring between postoperative baseline radiographs (made within 6 weeks after surgery) and follow-up radiographs required that the 2 sets of radiographic views were closely comparable. Comparability of true Grashey anteroposterior radiographs made at the postoperative baseline and at the time of follow-up was determined by ensuring that the projection of the acromioclavicular joint and the

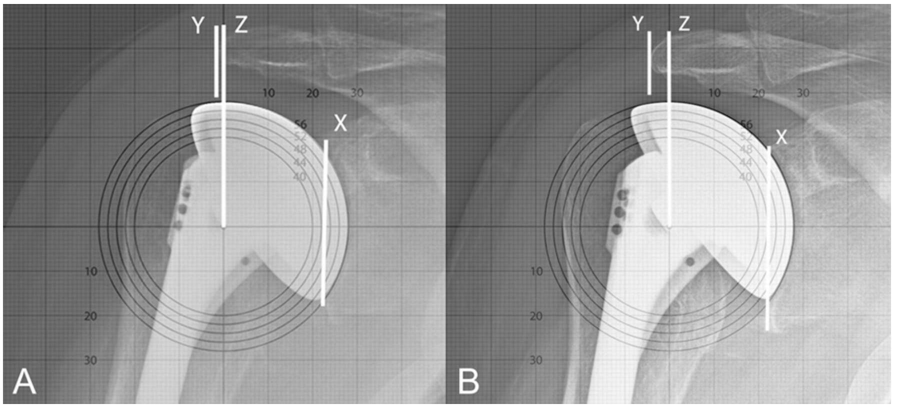


Fig. 3
When comparable postoperative baseline (**Fig. 3-A**) and follow-up (**Fig. 3-B**) radiographs were available, the medial-lateral positions of the humeral head relative to the scapula were measured on each, using a transparent template placed over the radiograph displayed on a PACS monitor. The displayed size of each radiograph was scaled so that the image of the prosthetic humeral head matched the size of the prosthesis used at surgery. Line X connects the superior and inferior lips of the glenoid. The template is oriented parallel to this line. Line Y is drawn parallel to line X passing through the lateral extent of the acromion. Line Z is drawn parallel to X passing through the center of a circle fit to the curvature of the humeral head. The distance between lines Y and Z indicates the medial-lateral position of the head center relative to the scapula. The change in the Y-Z distance from comparable postoperative baseline to follow-up radiographs indicates the amount of medialization.

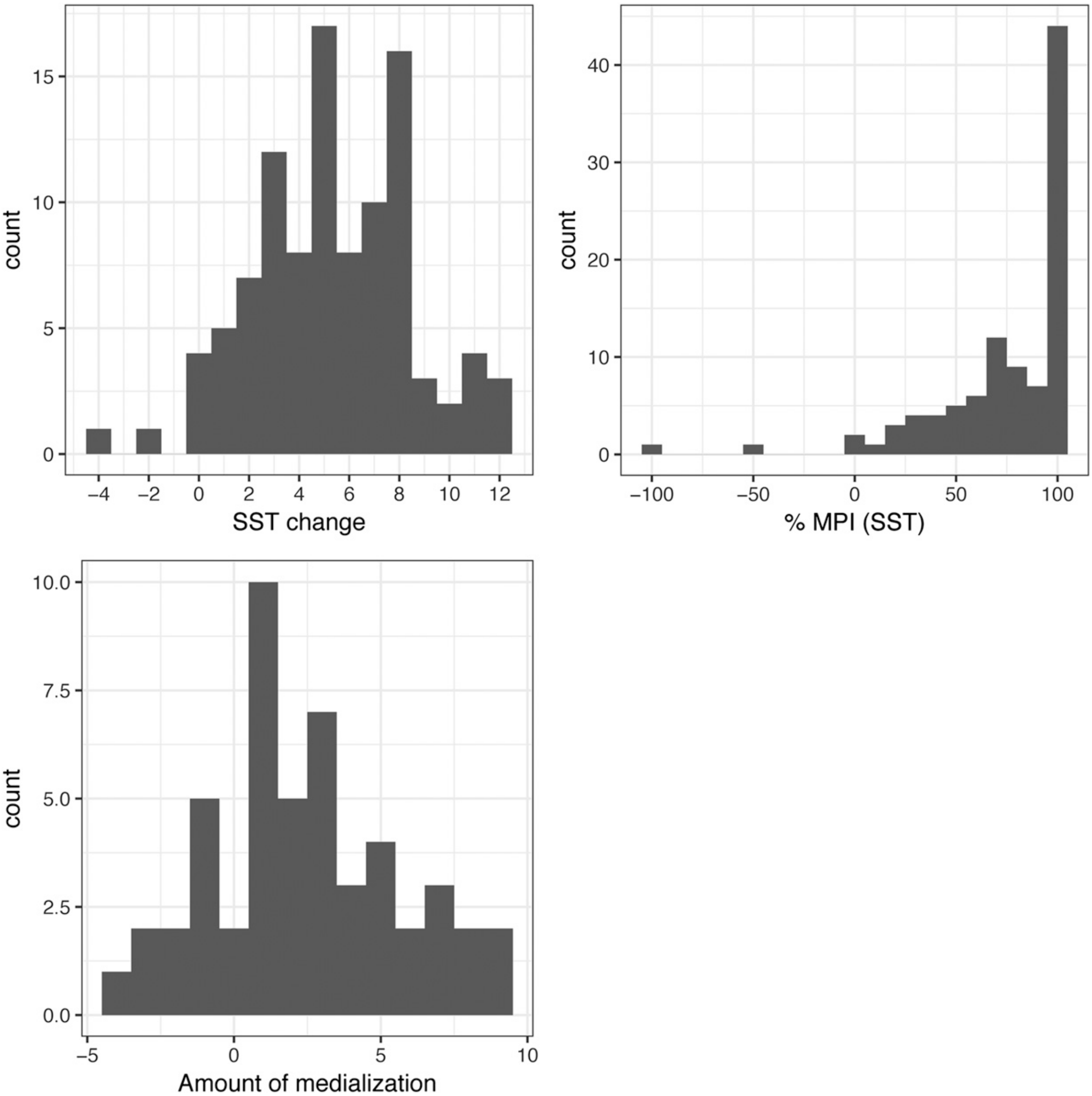


Fig. 4

Histogram plots demonstrating non-normal distribution of the preoperative-to-postoperative change in the SST (ΔSST), the percentage of maximum possible improvement in SST (% MPI), and the amount of humeral head medialization expressed in millimeters.

location of the overlap between the scapular neck and the rib cage were essentially identical on both radiographs. When these criteria were not met for an individual shoulder, the amount of medialization for that shoulder could not be determined and that shoulder was excluded from the medialization analysis. On comparable radiographs, the medial-lateral position of the humeral head relative to the scapula was measured using a template placed over the radiograph displayed on a Picture Archiving and Communication System (PACS) monitor (Fig. 3). Using this method, 3 shoulder surgeons not involved with the care of these patients (J.S.S., J.E.H., and B.C.S.) measured the medialization on pairs of postoperative baseline and follow-up radiographs for 10 randomly selected shoulders. To establish intrarater reliability, 2 raters (J.S.S. and J.E.H.) conducted a second measurement of all radiographs 2 weeks after the first set of measurements. The reproducibility data were analyzed using a variance components analysis. The interrater and intrarater variability results are presented as the percent of overall variation that is attributable to the interrater and intrarater variability (the sum of the interrater and intrarater percentages is the intraclass correlation; ICC). ICCs are classified as follows: ≤0.20 indicates poor agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, good agreement; and 0.81 to 1.00, excellent agreement[30]. Good to excellent agreement was achieved: the ICCs for the radiographic measurements were 0.79 for the baseline radiographs, 0.93 for the final radiographs, and 0.89 for the amount of medialization.

For the shoulders having standardized follow-up radiographs made between 18 and 30 months after surgery that were comparable with the postoperative baseline radiographs, we determined the medialization as the difference in humeral head position on the 2 sets of radiographs. For the shoulders having standardized follow-up radiographs made >30 months after surgery that were comparable with the postoperative baseline radiographs, the 24-month medialization was estimated by linear interpolation using the

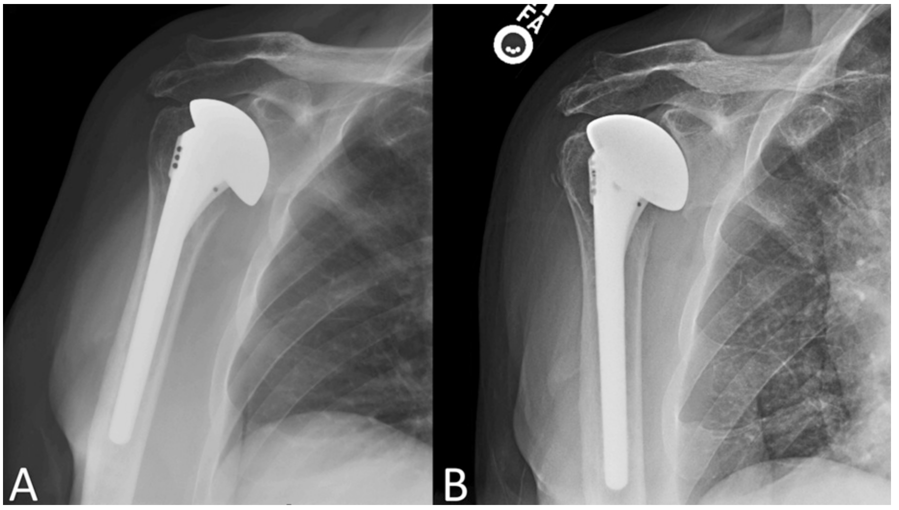


Fig. 5
Baseline postoperative (**Fig. 5-A**) and 2-year (**Fig. 5-B**) radiographs after a ream-and-run arthroplasty showing below-average medialization (1 mm).

medialization seen at the time point prior to 24 months and the time point after 24 months. Shoulders having open revision <18 months after surgery were not included in the radiographic analysis.

### *Statistical Methods*

Because the clinical and radiographic outcomes showed non-normal distributions (Fig. 4), we used nonparametric methods to assess the association between the patient, shoulder, and surgical characteristics and the clinical and radiographic outcomes. We used the Spearman correlation to test the association of the outcomes with continuous and ordinal characteristics. We used the median and the interquartile range (IQR) to describe the association of the outcome with categorical characteristics and tested it using the Kruskal-Wallis test.

To detect possible selection bias, we compared preoperative characteristics between shoulders with comparable radiographs from which medialization could be determined and those without comparable radiographs. We also compared preoperative characteristics for shoulders with medialization data based on the measurement of follow-up radiographs within the 18 to 30-month window and those for which medialization was determined by interpolation from radiographs made >30 months after surgery. The 2-sample t test, the chi-square test, or the Fisher exact test was used to test for differences between the groups.

All calculations were carried out in R (version 3.3.0; R Foundation for Statistical Computing)[31]. A p value of <0.05 was used to denote significance. P values were not adjusted for multiple comparisons.

## Results

### *Participants*

Between August 24, 2010, and October 22, 2013, 150 consecutive shoulders had the ream-and-run procedure performed by the senior surgeon. For the 8 patients having the

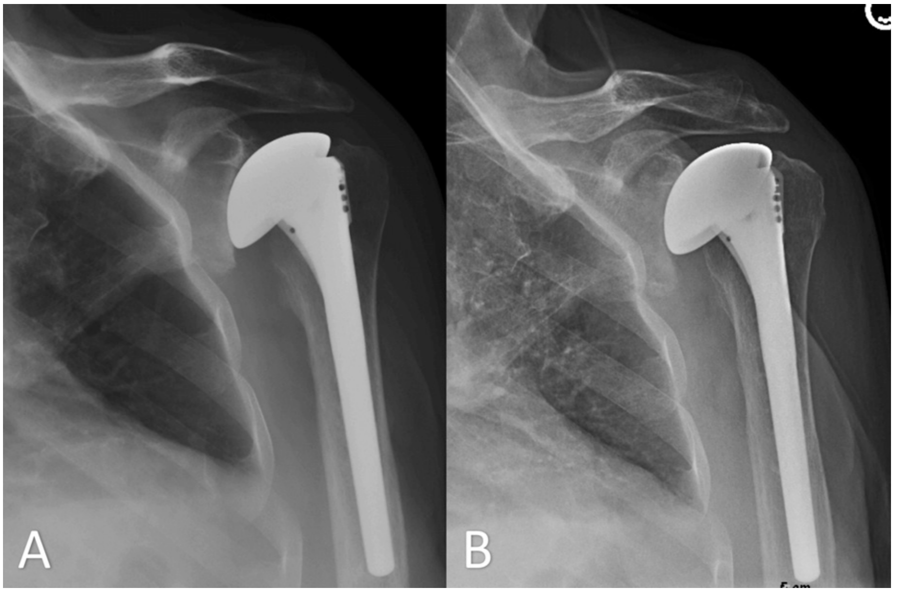


Fig. 6
Baseline postoperative (**Fig. 6-A**) and 2-year (**Fig. 6-B**) radiographs after ream-and-run arthroplasty showing above-average medialization (9 mm).

**TABLE II Univariate Analysis for SST Change and Percentage of Maximum Possible Improvement***

| | SST Change | | | Percentage of MPI in SST | | |
|---|---|---|---|---|---|---|
| | No.† | Median (IQR) or Correlation‡ | P Value§ | No.† | Median (IQR) or Correlation‡ | P Value§ |
| Age | 101 | −0.12 | 0.2 | 99 | 0.05 | 0.6 |
| Sex | 101 | | 0.8 | 99 | | 0.2 |
| Female | 5 | 5.0 (4.0 to 7.0) | | 5 | 71 (40 to 78) | |
| Male | 96 | 5.0 (3.0 to 8.0) | | 94 | 88 (62 to 100) | |
| ASA classification# | 101 | | 0.7 | 99 | | 0.7 |
| I | 25 | 5.0 (3.0 to 7.0) | | 25 | 88 (70 to 100) | |
| II | 63 | 5.0 (3.0 to 8.0) | | 61 | 86 (60 to 100) | |
| III | 13 | 7.0 (4.0 to 8.0) | | 13 | 89 (50 to 100) | |
| Alcohol | 101 | | 0.09 | 99 | | 0.4 |
| No | 31 | 7.0 (4.0 to 8.0) | | 31 | 89 (74 to 100) | |
| Yes | 70 | 5.0 (3.0 to 7.0) | | 68 | 86 (54 to 100) | |
| Smoking history | 101 | | 0.8 | 99 | | 0.4 |
| Never | 67 | 5.0 (3.0 to 8.0) | | 66 | 86 (67 to 100) | |
| Passive | 3 | 6.0 (4.5 to 7.5) | | 3 | 100 (75 to 100) | |
| Quit | 29 | 5.0 (3.0 to 8.0) | | 28 | 78 (50 to 100) | |
| Yes | 2 | 4.5 (NA) | | 2 | 100 (NA) | |
| Body mass index | 101 | 0.15 | 0.13 | 99 | 0.1 | 0.3 |
| Preop. scapular body-glenoid angle** | 101 | 0.21 | 0.04 | 99 | 0.16 | 0.11 |
| Work-related condition | 101 | | 0.6 | 99 | | 0.1 |
| No | 96 | 5.0 (3.0 to 8.0) | | 94 | 87 (64 to 100) | |
| Yes | 5 | 5.0 (1.0 to 8.0) | | 5 | 42 (11 to 89) | |
| Prior shoulder surgery | 101 | | 0.9 | 99 | | 0.07 |
| No | 74 | 5.0 (3.0 to 8.0) | | 72 | 100 (66 to 100) | |
| Yes | 27 | 5.0 (3.5 to 7.0) | | 27 | 78 (56 to 96) | |
| Glenoid type | 101 | | 0.001 | 99 | | 0.050 |
| A1 | 1 | 3.0 (NA) | | 1 | 50 (NA) | |
| A2 | 37 | 8.0 (5.0 to 9.0) | | 37 | 100 (83 to 100) | |
| B1 | 17 | 3.0 (1.0 to 6.0) | | 17 | 100 (60 to 100) | |
| B2 | 46 | 5.0 (3.0 to 6.0) | | 44 | 75 (54 to 100) | |
| Surgery year | 101 | −0.01 | 0.9 | 99 | 0.01 | 0.9 |
| Head diameter in mm | 101 | | 0.5 | 99 | | 0.06 |
| 52 | 6 | 7.0 (4.8 to 7.8) | | 5 | 100 (100 to 100) | |
| 56 | 95 | 5.0 (3.0 to 8.0) | | 94 | 83 (62 to 100) | |
| Head height in mm | 101 | | 0.6 | 99 | | 0.5 |
| 15 | 4 | 5.5 (4.0 to 6.5) | | 4 | 76 (51 to 92) | |
| 18 | 54 | 5.5 (3.0 to 8.0) | | 54 | 86 (57 to 100) | |
| 21 | 41 | 5.0 (3.0 to 8.0) | | 39 | 83 (65 to 100) | |
| Other | 2 | 3.0 (NA) | | 2 | 100 (NA) | |
| Antibiotics | 101 | | 0.8 | 99 | | 0.6 |
| Cefazolin | 44 | 5.0 (3.0 to 8.0) | | 44 | 82 (66 to 100) | |
| Ceftriaxone | 3 | 5.0 (3.5 to 5.5) | | 3 | 71 (48 to 86) | |
| Clindamycin | 7 | 4.0 (3.5 to 6.5) | | 7 | 89 (61 to 100) | |
| Vancomycin and ceftazidime | 1 | 3.0 (NA) | | 1 | 33 (NA) | |
| Vancomycin and ceftriaxone | 46 | 5.0 (3.2 to 7.8) | | 44 | 96 (62 to 100) | |

*continued*

**TABLE II (*continued*)**

| | SST Change | | | Percentage of MPI in SST | | |
|---|---|---|---|---|---|---|
| | No.† | Median (IQR) or Correlation‡ | P Value§ | No.† | Median (IQR) or Correlation‡ | P Value§ |
| Normal biceps | 101 | | 1 | 99 | | 0.8 |
| Yes | 90 | 5.0 (3.0 to 8.0) | | 88 | 87 (62 to 100) | |
| No | 11 | 6.0 (3.0 to 7.5) | | 11 | 86 (68 to 100) | |
| Rotator interval plication | 101 | | 0.3 | 99 | | 0.8 |
| No | 78 | 5.0 (3.0 to 8.0) | | 76 | 87 (54 to 100) | |
| Yes | 23 | 5.0 (5.0 to 7.5) | | 23 | 83 (69 to 100) | |
| Humeral component | 101 | | 0.9 | 99 | | 0.03 |
| Eccentric | 26 | 5.0 (3.2 to 7.8) | | 26 | 73 (57 to 85) | |
| Noneccentric | 75 | 5.0 (3.0 to 8.0) | | 73 | 100 (70 to 100) | |
| Joint space present at 2 yr | 50 | | 0.6 | 49 | | 0.2 |
| No | 31 | 5.0 (3.5 to 7.5) | | 30 | 94 (68 to 100) | |
| Yes | 19 | 5.0 (2.5 to 6.5) | | 19 | 75 (56 to 100) | |
| Superior decentering at 2 yr | 53 | 0.05 | 0.7 | 52 | −0.11 | 0.4 |
| Inferior osteophyte on 2-yr radiograph | 53 | | 0.2 | 52 | | 0.6 |
| No | 21 | 5.0 (2.0 to 5.0) | | 20 | 85 (48 to 100) | |
| Yes | 32 | 5.0 (3.0 to 8.0) | | 32 | 84 (62 to 100) | |

*As an example of the change in SST and the percentage of maximum possible improvement, a shoulder with a preoperative SST of 1 and postoperative SST of 4 is contrasted with another having a preoperative SST of 7 and a postoperative SST of 10. Both would have an SST change of 3. However, as the maximum score on the SST is 12, the former would have a percentage of MPI of 27% (3/[12−1]) and the latter a percentage of MPI of 60% (3/[12−7]). †There were 101 shoulders with minimum 2-year clinical follow-up data and 99 with data on percentage of MPI as 2 patients had a starting SST of 12 with resultant undefined percentage of MPI. Adequate radiographs were available for evaluation of an inferior osteophyte and superior decentering in 53 shoulders and for evaluation of a radiographic joint space in 50 shoulders. ‡The Spearman correlation was used to test the association of the outcomes with continuous and ordinal characteristics, and the median and the interquartile range (IQR) were used to describe the association with categorical characteristics and were tested with the Kruskal-Wallis test. IQR was calculated only if n >2. NA = not available. §Kruskal-Wallis test or Spearman correlation test. We also carried out an alternative analysis using linear regression with confidence intervals and p values calculated by nonparametric bootstrap (999 resamples)[31]. The linear regression approach allowed covariate adjustments (baseline SST for SST change and percentage of MPI, and baseline medialization and years to the follow-up radiographs for the medialization change). The bootstrap criterion was used for characteristics present in <20 of the shoulders. In almost all cases, the conclusions from the bootstrap analyses were similar to those from the Spearman correlation and Kruskal-Wallis tests. #ASA = American Society of Anesthesiologists. **Glenoid retroversion is 90° minus the scapular body-glenoid angle.

procedure performed on both shoulders, only the first of the 2 shoulders was included. Of the remaining 142 eligible shoulders, 132 patients (132 shoulders) consented to enroll in our study. Two-year clinical outcomes were available for 120 of these shoulders.

After the exclusion of patients with other indications for shoulder arthroplasty typical of active patients (such as secondary degenerative joint disease, capsulorrhaphy arthropathy, posttraumatic arthropathy, and chondrolysis), 111 patients were identified with primary osteoarthritis. The 101 patients with primary osteoarthritis and 2-year clinical outcomes formed the basis for this analysis (Fig. 1). Comparable baseline and follow-up standardized radiographs at ≥18 months after surgery were available for 50 shoulders. Representative radiographs showing less and more medialization are shown in Figures 5 and 6, respectively.

The patients had a mean age (and standard deviation) of 60 ± 9 years (range, 35 to 80 years) and were predominantly male (105 [95%] of 111; Table I). Preoperatively, nearly half (49; 44%) had type-B2 glenoid morphology (Fig. 2-B)[32]. The mean scapular body-glenoid angle was 69° ± 12° (range, 40° to 95°) preoperatively (glenoid version is calculated as 90° minus the scapular body-glenoid angle)[23].

For patients with both baseline and follow-up SST scores, the mean score improved from 4.9 ± 2.8 at baseline to 10.3 ± 2.4 at the latest follow-up ($p < 0.001$). On average, patients improved by three-quarters of the maximum possible improvement in the SST score (the mean percentage of the maximum possible improvement [% MPI] achieved was 75% ± 34%). The mean SST score at baseline for the 10 patients without a follow-up SST score was 5.4 ± 3.0.

### *Factors Associated with 2-Year Clinical Outcome*

The univariate analysis (Table II) indicated that preoperative glenoid morphology was significantly associated ($p = 0.001$)

**TABLE III Multivariate Linear Regression Analysis for SST Change and % MPI***

| | SST Change† (N = 101) | | Percentage of MPI in SST† (N = 99) | |
|---|---|---|---|---|
| | Coefficient (95% CI) | P Value | Coefficient (95% CI) | P Value |
| Preop. SST, per 1 point | −0.7 (−0.9 to −0.5) | <0.001 | −1 (−4 to 2) | 0.6 |
| Preop. scapular body-glenoid angle, per 10° | 0.2 (−0.2 to 0.6) | 0.4 | | |
| Humeral component | | | | |
| Eccentric (n = 26) | | | 0.0 (reference) | |
| Noneccentric (n = 75) | | | 10 (−4 to 25) | 0.2 |
| Glenoid type | | | | |
| A1 (n = 1) | −1.7 (−2.9 to −0.4)‡ | 0.009‡ | | |
| A2 (n = 37) | 1.0 (−0.2 to 2.2) | 0.09 | | |
| B1 (n = 17) | −0.3 (−2.0 to 1.3) | 0.8 | | |
| B2 (n = 46) | 0.0 (reference) | | | |

*All predictors with p < 0.05 in the univariate analysis were included in the model for each outcome. Multivariate analysis was carried out using linear regression with bootstrapping (9,999 resamples) for calculating the confidence intervals (CIs) and p values for the effect of the different characteristics. Variables with p < 0.05 in the univariate analysis (either by the Spearman correlation or Kruskal-Wallis tests) were included in the models. Baseline SST was forced into the model for the SST change and for the % MPI in SST. †The 95% CI and p value were calculated by a nonparametric bootstrap with 9,999 resamples. The model goodness of fit ($R^2$) was 0.53 for SST change and 0.017 for % MPI in SST and the $R^2$ (strongest predictor) was 0.48 for preoperative SST change and 0.015 for % MPI in SST for an eccentric humeral component. ‡Based on n = 1. The reported bootstrap confidence interval and p value are very approximate (and anticonservative) in such a small sample size.

with ΔSST: shoulders with a type-A2 glenoid had greater median improvement (median change, +8; IQR, 5 to 9) than those with a type-B1 glenoid (median change, +3; IQR, 1 to 6) or a type-B2 glenoid (median change, +5; IQR, 3 to 6). Preoperative scapular body-glenoid angle (glenoid version) was positively and significantly correlated with ΔSST (r = 0.21, p = 0.04). The corresponding results for the % MPI are also shown in Table II. With the exception of the association of humeral head eccentricity with the % MPI (p = 0.03), the remaining factors assessed (age, sex, American Society of Anesthesiologists [ASA] score, alcohol use, smoking history, body mass index [BMI], a work-related injury, prior shoulder surgery, year of surgery, humeral head implant size, rotator interval plication, and antibiotic

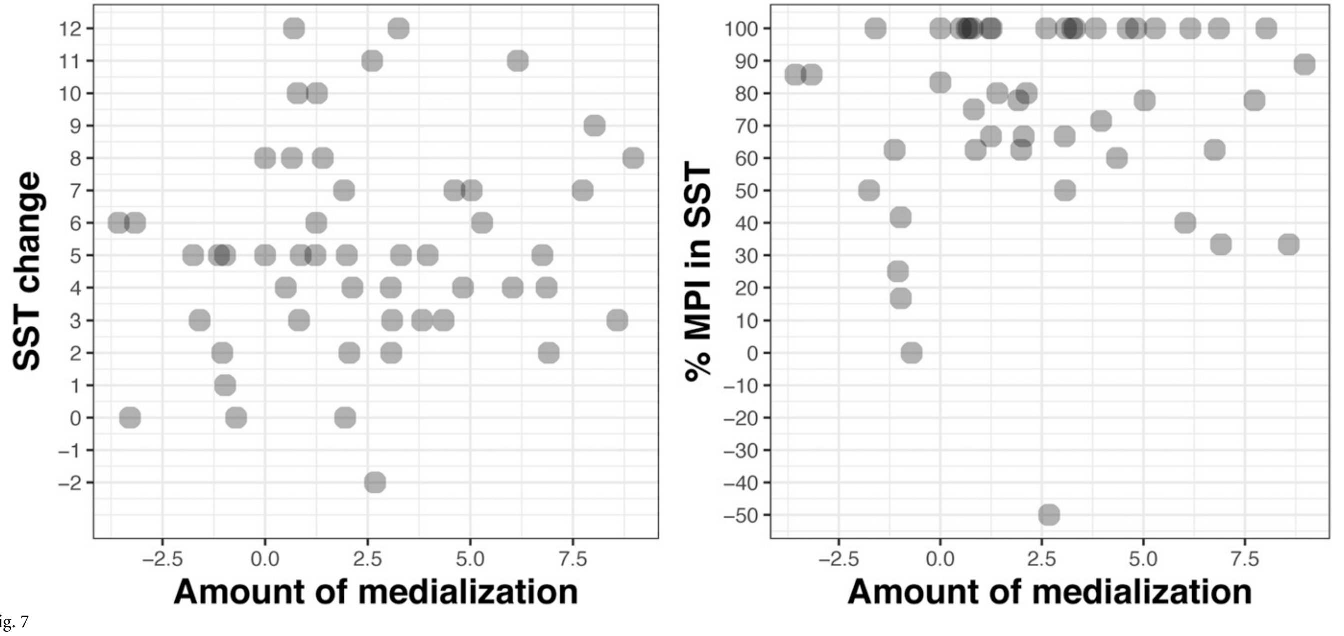


Fig. 7
SST change and percentage of maximum possible improvement (% MPI) as a function of 2-year radiographic medialization expressed in millimeters.

selection) did not show significant associations with ΔSST or % MPI.

Multivariate analysis revealed that the improvement in the SST score was significantly better for shoulders with lower preoperative SST scores and a type-A2 glenoid (Table III). The corresponding results for the % MPI are also shown in Table III. Although shoulders with a type-A2 glenoid had the best clinical outcomes, it is of note that the most common glenoid type in this series was B2 (46%) and these 46 shoulders had significant clinical improvement in terms of both change in SST and percentage of maximum improvement, second only to shoulders with a type-A2 glenoid (Table II).

### *Factors Associated with 2-Year Medialization of the Humeral Head*

For the 50 shoulders for which comparable standardized radiographs were available both at postoperative baseline and at ≥18 months after surgery, the mean medialization of the humeral head prosthesis relative to the scapula was 2.4 ± 3.2 mm (range, −3.6 to 9.0 mm) at a mean of 28 ± 6 months postoperatively. The univariate analysis revealed that age, sex, ASA classification, smoking history, alcohol use, BMI, work-related injury, prior shoulder surgery, glenoid-scapular body angle, glenoid type, antibiotic use, use of an eccentric humeral component, and rotator interval plication were not significantly associated with the amount of medialization (see Appendix).

### *Association of Radiographic and Clinical Self-Assessment Outcomes*

There was no significant association between the amount of medialization and the change in SST (r = 0.10) or % MPI in SST score (r = 0.10) (Fig. 7). Radiographic evidence of a joint space between the humeral head prosthesis and the glenoid was noted in 19 (38%) of 50 patients. Patients with and without this radiographic joint space did not have significant differences in ΔSST (p = 0.6) or % MPI of SST (p = 0.2). In addition, 32 (60%) of 53 patients were noted to have an inferior glenoid osseous prominence on the latest radiographs; this also did not show a significant association with ΔSST (p = 0.2) or % MPI (p = 0.6).

In comparison with patients who had ≤5 mm of medialization, those with >5 mm of medialization (n = 11) at the time of follow-up did not show a significantly different change in the SST (median ΔSST was 6.0 [IQR, 4.0 to 7.5] for those with >5 mm of medialization versus 5.0 [IQR, 3.0 to 6.5] for those with ≤5 mm of medialization; p = 0.3) or a significantly different % MPI (median % MPI was 78% [IQR, 51% to 100%] for those with >5 mm of medialization versus 80% [IQR, 63% to 100%] for those with ≤5 mm of medialization; p = 0.8). In comparison with patients who had improved clinical outcomes, those who showed no improvement from the preoperative SST (n = 4) did not have a significantly different amount of medialization (median medialization was 0.6 mm [IQR, –1.4 to 2.1 mm] for those with ΔSST of ≤0 versus 2.1 mm [IQR, 0.7 to 4.8 mm] for those with ΔSST of >0; p = 0.2).

### *Analysis of Incomplete Follow-up*

Compared with the 101 patients with clinical follow-up, the 10 patients without clinical follow-up were more likely to have a classification of ASA II (100% versus 62%; p = 0.01) or a work-related injury (30% versus 5%; p = 0.02). Compared with the patients with comparable radiographs, the patients without comparable radiographs had a higher BMI (mean, 29.5 kg/m$^2$ versus 27.8 kg/m$^2$; p = 0.048), were more likely to have a work-related injury (11% versus 5%; p = 0.07) and a prosthetic humeral head height of 18 mm (69% versus 54%; p = 0.006 for the comparison of the 3 head heights), and were less likely to have rotator interval plication (16% versus 23%; p = 0.09) and an eccentric humeral component (16% versus 26%; p = 0.005).

### *Subsequent Procedures*

Fourteen shoulders underwent subsequent procedures. Four patients underwent closed manipulation under anesthesia for persistent stiffness. Seven patients underwent single-stage exchange of the humeral component and soft-tissue releases because of pain and stiffness; 6 of them had cultures positive for

**TABLE IV Published Outcomes of Ream-and-Run Arthroplasty**

| Study | No. of Patients | Mean SST* | | Mean Follow-up Period *(mo)* | Repeat Procedures* |
|---|---|---|---|---|---|
| | | Preop. | Postop. | | |
| Lynch et al.[6] (2007) | 35 | 4.7 | 9.4 | 32 | 3.9% |
| Clinton et al.[7] (2007) | 35 | 4.5 | 9.5 | 31 | NR |
| Saltzman et al.[8] (2011) | 65 | 4.1 | 9.5 | 43 | 13.8% |
| Gilmer et al.[5] (2012) | 140 | 4.6 | 10.0 | 54 | 15.7% |
| Kearns et al.[11] (2013) | 36 | NR | 7.9 | 28 | 13.8% |
| Somerson and Wirth[9] (2015) | 17 | 3.2 | 10.0 | 47 | 17.6% |
| Present study | 111 | 4.9 | 10.3 | 28 | 12.6%† |

*NR = not reported. †Subsequent procedure rate includes all subsequent procedures, including manipulation under anesthesia.

Propionibacterium at the time of revision. Three patients had revision to total shoulder arthroplasty (1 culture was positive for Propionibacterium, and 1 revision was performed at an outside institution without culture data available). Among the 50 patients with radiographic follow-up, the mean radiographic medialization was 1.8 ± 1.3 mm for the 2 who had revision compared with 2.4 ± 3.2 mm for the 48 who had not had revision (p = 0.6).

## Discussion

In response to our first question, we found no patient, shoulder, or surgical characteristic that was significantly associated with the amount of medialization. In response to our second question, we found that clinical outcomes were not significantly associated with the amount of medialization.

The self-reported clinical outcomes and rates of subsequent procedures of the cohort in the present study using prospectively collected data (a mean 2-year SST of 10.3 ± 2.4 and mean ΔSST from baseline to 2-year follow-up of 5.4 ± 2.6) are comparable with prior retrospective studies (Table IV)[5-9,13]. Although shoulders with a type-A2 glenoid had the best clinical outcomes, it is of note that the group of 46 shoulders with a type-B2 glenoid (the glenoid type most frequently encountered in these cases) had significant clinical improvement in terms of both change in SST and percentage of maximum improvement (Table II). It is also of interest that many of the shoulders in this study had substantial preoperative glenoid retroversion: the average retroversion was 21° ± 12° (range, −5° to 50°). These observations suggest that the surgical techniques applied in the present investigation can be effective in the management of arthritic shoulders with a retroverted biconcave glenoid.

The management of glenohumeral arthritis in individuals wishing high levels of activity is a challenge[16,17,33]. As noted in a recent review article, "Despite general reports of high long-term survivorship, implant failure and functional deterioration after total shoulder arthroplasty are major concerns in the management of younger patients. In addition to having a longer life expectancy, younger patients also tend to be more active and can be expected to place greater demands on their shoulder arthroplasty."[34] The complication and reoperation rates for total shoulder replacements in a young, active population have been reported to be 46% and 23%, respectively[35]. The complication rate of humeral hemiarthroplasty combined with biological glenoid resurfacing has been deemed "unacceptable" by multiple authors[18,36-38]. Furthermore, younger individuals tend to have a more varied mix of arthritis types in comparison with their older counterparts[39]. Finally, young male patients, such as those in the present report, have a disproportionately high risk of infection with Propionibacterium[40], infections that are particularly problematic to manage if a glenoid component is in place.

These observations point out the difficulties in managing glenohumeral arthritis in the active person. While we continue to offer the ream-and-run procedure to highly motivated and highly active patients with glenohumeral arthritis, we are diligent in letting prospective candidates know of the risk of stiffness and Propionibacterium infection as well as the possible need for subsequent procedures.

The results of this study should be considered in light of certain limitations. First, many of our patients live >100 miles from our center; this factor compromised our ability to obtain follow-up standardized radiographs that met our criteria for comparability with the baseline postoperative radiographs. Second, the procedures were performed by a shoulder surgeon with substantial experience in this technique; these results may not be generalizable to all practices. Third, the present study assessed the findings at an average of 28 months; it is possible that longer periods of follow-up would yield different results for clinical and radiographic outcomes. Fourth, the present study did not distinguish between humeral medialization and glenoid erosion; it is possible that subtle differences in radiographic images or posterior humeral subluxation affected the apparent relationship of the humeral head to the glenoid. Fifth, it was noted that, in some shoulders, the humeral head appeared to be lateralized rather than medialized. This observation has been made in a prior report[13]. While this could be a measurement error, it could also be due to the growth of a fibrocartilaginous layer between the glenoid bone and the humeral head prosthesis as previously described in an animal model[41]. Sixth, the results of this different and more recent cohort are somewhat different than those of our prior report[5]. The differences may be due to evolution in patient selection or surgical technique, or to different numbers of patients in the different subgroups.

In conclusion, we believe that this is the largest reported series of ream-and-run procedures with radiographic follow-up and is the first to explore in detail the possible relationship between clinical and radiographic outcomes. The results demonstrate that in an active, predominantly male population wishing to avoid a prosthetic glenoid component, the ream-and-run procedure was effective in improving shoulder comfort and function for osteoarthritic shoulders with a range of glenoid pathologies, including retroversion and type-B2 morphology. The 2-year clinical outcome was not significantly related to the amount of medialization. Further study will be necessary to determine whether medialization affects the clinical outcome with follow-up of >2 years.

## Appendix

eA A table showing the univariate analysis for medialization is available with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/D435). ■

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