J Shoulder Elbow Surg (2019) 28, 1666–1673

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Mid- to long-term follow-up of shoulder arthroplasty for primary glenohumeral osteoarthritis in patients aged 60 or under

Lionel Neyton, MD[a], Jacob M. Kirsch, MD[b,*], Philippe Collotte, MD[a], Philippe Collin, MD[c], Louis Gossing, MD[a], Mikael Chelli, MD[a], Gilles Walch, MD[a]

[a]*Ramsay Générale de Santé, Hôpital Privé Jean Mermoz, Centre Orthopédique Santy, Lyon, France*
[b]*MedSport, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, MI, USA*
[c]*Department of Orthopaedic Surgery and Sports Medicine, Centre Hospitalier Privé Saint-Grégoire (Vivalto Santé), Saint-Grégoire, France*

Background: Shoulder arthroplasty in young patients with primary glenohumeral osteoarthritis is an area of continued controversy.
Methods: A retrospective multicenter study was performed for all patients aged 60 years or less undergoing either hemiarthroplasty (HA) or total shoulder arthroplasty (TSA) for primary glenohumeral osteoarthritis with a minimum of 24-month follow-up. Clinical and functional outcomes, complications, and need for revision surgery were analyzed. Survivorship analysis using revision arthroplasty as an endpoint was determined.
Results: A total of 202 patients with a mean age of 55.3 years (range, 36-60 years) underwent TSA with a mean follow-up of 9 years (range, 2-24.7 years). Revision arthroplasty was performed in 33 (16.3%) shoulders, with glenoid failure associated with the revision in 29 shoulders (88%). TSA survivorship analysis demonstrated 95% free of revision at 5 years, 83% at 10 years, and 60% at 20-year follow-up. A total of 31 patients with a mean age of 52.5 years (range, 38-60 years) underwent HA with a mean follow-up of 8.7 years (range, 2-21.4 years). Revision arthroplasty was performed in 5 (16.1%) shoulders, with glenoid erosion as the cause for revision in 4 shoulders (80%). HA survivorship analysis demonstrated 84% free from revision at 5 years and 79% at the final follow-up. TSA resulted in a significantly better range of motion, pain, subjective shoulder value, and Constant score compared with HA.
Conclusion: In young patients with primary glenohumeral osteoarthritis, TSA resulted in significantly better functional and subjective outcomes with no significant difference in longitudinal survivorship compared with patients treated with HA.
Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Shoulder arthroplasty; glenohumeral arthritis; primary arthritis; total shoulder arthroplasty; hemiarthroplasty

This study was approved by the Institutional Review Board of Vivalto Santé (IRB # CERC-VS-2018-06-4).

*Reprint requests: Jacob M. Kirsch, MD, University of Michigan, A. Alfred Taubman Healthcare Center, Floor 2, Reception B 2912 Taubman Center, 1500 East Medical Center Drive, Ann Arbor, MI 48109-5328, USA.

E-mail address: kirschj@med.umich.edu (J.M. Kirsch).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2019.03.006

Management of glenohumeral osteoarthritis in young patients is challenging and represents an area of continued controversy. Numerous treatment strategies have been proposed including arthroscopic management,[17,24,38] hemiarthroplasty (HA),[10,20,41,42,48] humeral head resurfacing,[2,27] HA with glenoid resurfacing,[18,43,47] total shoulder arthroplasty (TSA),[3,8,13,19,33,34] and reverse TSA.[12,36] Despite the reliable benefits of shoulder arthroplasty on pain and functional improvement,[10,14,22,26,28,49,50] concerns pertaining to implant longevity and the need for revision surgery in a population that often desires to return to an active lifestyle remain at the core of the treatment dilemma.[3,8-11,19,20,34,41,42]

The role of shoulder arthroplasty in young patients with primary glenohumeral osteoarthritis is not clearly defined. These patients represent only approximately 5% to 10% of the shoulder arthroplasty population.[3,33,39] Younger patients considering shoulder arthroplasty have higher preoperative expectations regarding their postoperative function, including the ability to return to sports and exercise.[16] Recent evidence suggests a high proportion of patients can return to demanding reactional activity or sports after shoulder arthroplasty.[23,35,50] However, outcomes for younger patients undergoing shoulder arthroplasty have not been as reliable.[3,8,34,41,42] In addition, most of the literature in young patients consists of smaller single-center studies with heterogeneous patient populations.[6,20,21,29,34,41,42]

The purpose of this multicenter study was to longitudinally evaluate young patients (≤60 years old) undergoing primary shoulder arthroplasty for primary glenohumeral osteoarthritis. We sought to evaluate functional and subjective outcomes and implant survivorship in patients undergoing HA compared with TSA. Our hypothesis was that patients treated with TSA would have better functional and subjective outcomes, but would have worse survivorship due to glenoid component loosening compared with HA.

Materials and method

A retrospective review from 1992 to 2016 was performed for all patients undergoing primary shoulder arthroplasty for symptomatic primary glenohumeral osteoarthritis across 9 centers. Inclusion criteria included age equal to or less than 60 years at the time of surgery, underlying diagnosis of primary glenohumeral osteoarthritis, primary shoulder arthroplasty with either a stemmed metallic HA or TSA, use of an all-polyethylene glenoid component for TSA, and a minimum follow-up of 2 years. Exclusion criteria consisted of diagnoses other than primary osteoarthritis, patients treated with revision arthroplasty, resurfacing arthroplasty, stemless arthroplasty, interposition arthroplasty (snooker ball) or reverse shoulder arthroplasty, TSA with a metal backed glenoid, and incomplete radiographic and clinical information at the final follow-up. Any surgical procedure after the initial arthroplasty where the components were retained was considered a reoperation, whereas if the components were removed or exchanged, it was considered a revision.

Table I Baseline demographic information for the entire cohort of patients undergoing either hemiarthroplasty (HA) or total shoulder arthroplasty (TSA) for primary glenohumeral arthritis

	HA (n = 31)	TSA (n = 202)	*P* value
Age at surgery (yr)	52.5 (38-60)	55.3 (36-60)	.003
Age at the last follow-up (yr)	61.2 (49-80)	64.3 (47-78)	.016
Sex (male) (%)	48.4	49.5	.9
Duration of follow-up (yr)	8.7 (2-22.4)	9 (2-24.7)	.76

Baseline demographics for all patients undergoing primary shoulder arthroplasty. Data are expressed as means with range in parentheses.

During the study period, we identified 233 shoulders with a diagnosis of primary glenohumeral osteoarthritis, which were treated with a primary HA or TSA. Of this cohort, 202 patients with a mean age of 55.3 years (range, 36-60 years) underwent TSA and 31 patients with a mean age of 52.5 years (range, 38-60 years) underwent HA (Table I). Of the patients treated with TSA, 10 (5%) required a reoperation and 33 (16.3%) required a revision shoulder arthroplasty. Of the patients treated with HA, 4 (12.9%) required a reoperation and 5 (16.1%) required revision shoulder arthroplasty.

Complete preoperative and postoperative clinical and radiographic data were available for 155 patients who underwent TSA and were free from revision arthroplasty at a mean final follow-up of 8.3 years (range, 2-24.7 years). Similar data were available for 21 patients treated with HA at a mean final follow-up of 9.9 years (range, 2-22.4 years) (Table II).

Clinical analysis

Preoperative and postoperative clinical and demographic data were assessed and recorded independently at each institution. Range of motion (ROM) was assessed using a goniometer and consisted of active forward flexion in the scapular plane and external rotation with the arm at the side and at 90° of abduction. Internal rotation was measured based on a 10-point scale designed to limited measurement bias when assessing internal rotation after

Table II Demographic information for patients undergoing either hemiarthroplasty (HA) or total shoulder arthroplasty (TSA) who were free from revision

	HA (n = 21)	TSA (n = 155)	*P* value
Age at surgery (yr)	52.5 (38-60)	55.7 (36-60)	.065
Age at the last follow-up (yr)	62.4 (52-80)	64 (47-77)	.19
Sex (male) (%)	57.1	50.3	.56
Duration of follow-up (yr)	9.9 (2-22.4)	8.3 (2-24.7)	.25

Baseline demographics for all patients free from revision shoulder arthroplasty at follow-up. Data are expressed as means with range in parentheses.

shoulder arthroplasty.[44] Additional outcome measures such as the Constant score[32] and the subjective shoulder value (SSV)[15] were assessed. Pain was evaluated based on the 15-point scale from the Constant score where a score of 0 represents the maximum pain and a score of 15 represents no pain.

Radiographic analysis

Standardized plain radiographs as well as advanced imaging were obtained to evaluate the status of the rotator cuff and to better characterize glenoid morphology. Computed tomography or magnetic resonance imaging was available in 175 patients undergoing TSA and all 31 patients undergoing HA and was used to classify the glenoid type according to Walch's classification.[4,46] Among patients undergoing TSA, there were 48 (27.4%) A1, 33 (19%) A2, 39 (22.3%) B1, 44 (25.1%) B2, 4 (2.3%) B3, 6 (3.4%) C, and 1 (0.6%) D glenoids. Among patients undergoing HA, there were 7 (26%) A1, 5 (18.5%) A2, 2 (7.4%) B1, 7 (26%) B2, and 6 (22.2%) C glenoids. Postoperative radiographs were evaluated for signs of humeral and glenoid component failure, per-implant radiolucent lines, and progressive glenoid erosion in patients treated with HA. For patients treated with TSA, radiolucent lines (RLL) were assessed at 6 different locations around the glenoid and given a score of 0 to 3 at each location for a total score of 0 to 18.[25] Similar to Denard et al,[8] an RLL score of $\geq$12 was considered to signify radiographic loosening and when glenoid component migration was evident, a maximum score of 18 was assigned.

Surgical technique

Various types of implants were used at the surgeon's discretion for both HA and TSA; however, all included patients had stemmed humeral implants with metallic heads. A total of 190 standard length stems and 43 short stem humeral components were used, of which 223 of 233 (96%) were Tornier Aequalis or Ascend Flex stems. Only cemented all-polyethylene glenoid components were included for patients undergoing TSA. The deltopectoral approach was used in 100% of patients. Management of the subscapularis also varied. The subscapularis was tenotomized in 64%, a subscapularis peel was used in 24%, and a lesser tuberosity osteotomy technique was used in 12%. The long head of the biceps was tenotomized or underwent tenodesis in 88.5% of patients.

Statistical analysis

Descriptive statistics were determined and expressed as means, ranges, and percentages. Preoperative and postoperative clinical outcome scores were compared using the Wilcoxon signed-rank test. Subgroup analysis was performed with the Mann-Whitney *U* test. A 2-tailed Student's *t*-test was used for unpaired data. Implant survivorship was assessed by the Kaplan-Meier method to estimate survival probabilities with 95% confidence intervals, and the Logrank nonparametric test for comparison of survival distributions was used to compare the survival differences between TSA and HA. The alpha risk was set to 0.05 for all tests to estimate statistical significance.

Results

Clinical results

At the final follow-up, 21 shoulders treated with HA and 155 shoulders treated with TSA were free of revision and had complete clinical data for assessment (Fig. 1). Comparison between patients undergoing HA and TSA who were free from revision demonstrated similar baseline demographics (Table II). Patients undergoing HA demonstrated significant improvement in ROM, pain, and Constant score (Table III). At the final follow-up, the mean subjective shoulder value was 69.9% (range, 30%-99%). For patients undergoing TSA, significant improvement was observed in ROM, pain, and Constant score (Table IV). At the final follow-up, the mean subjective shoulder value was 79.6% (range, 15%-100%).

Radiographic results

Postoperative radiographs of the 21 patients treated with HA who were free of revision surgery demonstrated glenoid erosion in 16 (76%) shoulders at the final follow-up. The extent of radiographic glenoid erosion appeared to progress over time. Patients without evidence of glenoid erosion had a mean follow-up of 4.9 years compared with a mean follow-up of 11.5 years in those patients with glenoid erosion. The small sample size limited meaningful analysis between shoulders with and without erosion; however, there was a trend toward worse functional outcome scores in those shoulders with glenoid erosion.

Postoperative radiographs of the 155 patients treated with TSA who were free of revision demonstrated a mean RLL score of 5.4 (range, 0-18). At a mean of follow-up 8.4 years, 23.8% (37) of TSAs had radiographic glenoid component loosening as denoted by an RLL score of $\geq$12. Patients with an RLL of $\geq$12 had significantly worse ROM in all planes, pain, SSV, and Constant score compared with those with an RLL $<$ 12 (Table V). Patients without radiographic evidence of glenoid loosening had a mean follow-up of 6.6 years compared with those with radiographic evidence of loosening who had a mean follow-up of 12.8 years.

Complications and survivorship

Postoperative complications occurred in 29% of shoulders treated with HA. The most common complications were progressive glenoid wear, followed by stiffness and pain. A total of 4 (12.9%) shoulders required reoperation and 5 (16.1%) shoulders required revision shoulder arthroplasty. Glenoid wear was the cause for revision arthroplasty in 4 of 5 (80%) shoulders. Survivorship analysis of HA with "revision" as the endpoint demonstrated successive drops over time with 89% of the cases free of revision at 3 years,

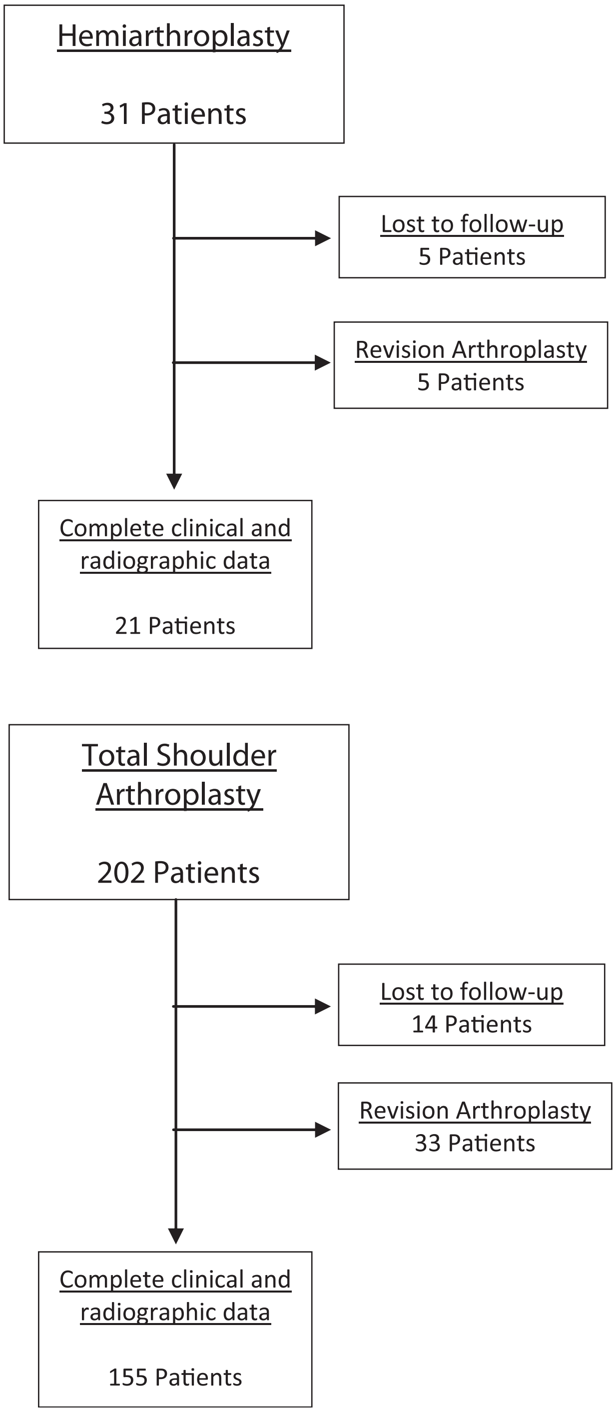

Figure 1 Flow chart depicting cohort selection.

84% at 5 years, and 79% after 8 years of follow-up. No further drop was observed after 8 years of follow-up (Fig. 2).

Postoperative complications occurred in 26.7% shoulders treated with TSA. The most common complication was glenoid loosening, which occurred in 39 (19.3%) shoulders. Overall, 10 (5%) reoperations and 33 (16.3%) revision arthroplasties were performed. Glenoid issues were associated with revision in 29 (88%) shoulders. The revision rates were not different between preoperative type A glenoids (A1 and A2) and type B glenoids (B1, B2, and B3) (14.1% vs. 20.5%, respectively; $P = .28$). Survivorship analysis of TSA with "revision" as the endpoint demonstrated successive drops over time with 95% free of revision at 5 years, 83% at 10 years, 68% at 15 years, and 60% at 20 years of follow-up (Fig. 2).

Table III Comparison of preoperative and postoperative range of motion and functional outcome scores of patients undergoing hemiarthroplasty who were free from revision

	Preoperative	Postoperative	*P* value
Active forward elevation (°)	109 (80-170)	136 (90-180)	<.05
External rotation with arm at side (°)	24 (−10 to 60)	27 (0-70)	>.05
Internal rotation (points)	4.6 (2-10)	5.6 (2-10)	>.05
Pain (points, 0-15)	5.8 (0-10)	10.3 (1-15)	<.01
Total Constant score (points)	44.3 (29-61)	59.8 (29.5-90)	<.01

Data are expressed as means with range in parentheses.

Hemiarthroplasty vs. total shoulder arthroplasty

Motion and function

At the final follow-up, patients free of revision who underwent TSA had significantly better ROM (except similar internal rotation), pain scores, and Constant score compared with those who underwent HA. Of note, the final SSV approached but did not reach statistical significance when comparing HA and TSA (69.9% vs. 79.6%, respectively; $P = .07$) (Table VI).

Table IV Comparison of preoperative and postoperative range of motion and functional outcome scores of patients undergoing total shoulder arthroplasty who were free from revision

	Preoperative	Postoperative	*P* value
Active forward elevation (°)	104 (30-170)	150 (30-180)	.0001
External rotation with arm at side (°)	13 (−40 to 70)	37 (0-60)	.0001
Internal rotation (points)	3.4 (0-8)	6.8 (2-10)	.0001
Pain (points, 0-15)	5.1 (0-13.5)	12.5 (0-15)	.0001
Total Constant score (points)	37.5 (8-71)	73.3 (27-95)	.0001

Data are expressed as means with range in parentheses.

Table V Range of motion, functional, and subjective outcomes in patients treated with total shoulder arthroplasty at the final follow-up comparing radiolucent line (RLL) scores

	RLL < 12	RLL ≥ 12	*P* value
Active forward elevation (°)	153 (90-180)	140 (30-180)	.005
External rotation at side (°)	39 (0-60)	30 (0-70)	.028
External rotation at 90° abduction (°)	66 (0-110)	56 (0-80)	.027
Internal rotation (points, 0-10)	6.9 (2-10)	6 (2-10)	.032
Pain (points, 0-15)	12.8 (5-15)	11.5 (0-15)	.033
Total Constant score (points)	74.4 (28-95)	67.7 (27-91)	.011
Subjective shoulder value (%)	82.8 (40-100)	72.6 (15-100)	.005

An RLL ≥ 12 signifies the radiographic appearance of a loose glenoid component. Data are expressed as means with range in parentheses.

Table VI Postoperative range of motion, functional, and subjective outcome scores of patients undergoing hemiarthroplasty (HA) and total shoulder arthroplasty (TSA) who were free from revision

	HA (n = 21)	TSA (n = 155)	*P* value
Active forward elevation (°)	136 (90-180)	149 (30-180)	.023
External rotation with arm at side (°)	27 (0-70)	37 (0-60)	.021
External rotation with arm abducted (°)	45 (10-90)	63 (0-110)	.046
Internal rotation (points)	5.6 (2-10)	6.7 (2-10)	.071
Pain (points, 0-15)	10.2 (1-15)	12.5 (0-15)	.034
Total Constant score (points)	59.8 (29.5-90)	72.6 (27-95)	.003
Subjective shoulder value (%)	69.9 (30-99)	79.6 (15-100)	.070

Data are expressed as means with range in parentheses.

Complications and survivorship

Patients requiring revision arthroplasty after HA tended to do so earlier relative to those patients who underwent TSA. The majority of revision arthroplasty occurred by 5 years in the HA group compared with 15 years in the TSA group. Despite the differences in survival probability at the final follow-up, comparative analysis demonstrated no significant difference between the survival distribution when comparing TSA with HA ($P = .91$). There was no significant difference in overall complications (29% vs. 26.7%; $P = .73$) or revision rate (16.1% vs. 16.3%; $P = .91$) when comparing HA with TSA.

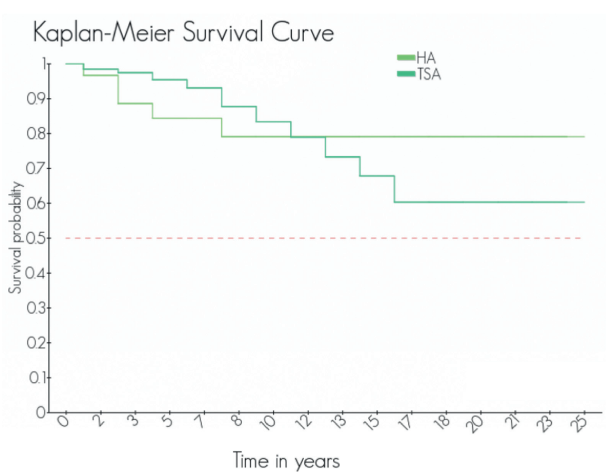

Figure 2 Kaplan-Meier survival curve for patients treated with hemiarthroplasty (HA; light green) and total shoulder arthroplasty (TSA; dark green) with revision arthroplasty as the endpoint.

Discussion

At mid-term to long-term follow-up, the results of this multicenter study demonstrate favorable functional and subjective outcomes for young patients undergoing HA or TSA for primary glenohumeral osteoarthritis. Comparative functional analysis demonstrated statistically significant differences between these cohorts favoring TSA. Despite survivorship analysis demonstrating earlier revision with HA and a more precipitous decline in the TSA group particularly after 10 years, there was no statistical difference in the rate of revision or the survival distribution when comparing TSA with HA in young patients with primary osteoarthritis.

The current literature pertaining to glenohumeral arthritis in young patients is limited by heterogeneity within the study population and a lack of generalizability based on single-center or single-surgeon studies. Patient demographics and underlying disease etiology can impact prognosis after shoulder arthroplasty.[9,30,33,39,42] Saltzman et al[33] evaluated more than 1000 TSAs and found that younger patients (<50 years) undergoing shoulder arthroplasty had more complex pathology compared with an older group of patients. These authors suggested that preoperative diagnosis may be a more important factor for postoperative outcomes than simply age alone.[33] Satisfaction and pain relief after shoulder arthroplasty have also been significantly associated with underlying disease etiology.[39]

Current data evaluating shoulder arthroplasty in young patients contain relatively few patients with primary osteoarthritis.[3,20,34,41,42] Sperling et al[41,42] reported on mostly patients with post-traumatic and rheumatoid arthritis, with only 8 patients in their series treated for primary osteoarthritis available for 20-year follow-up.[34] Levine et al[20] reported the results of 27 patients with long-term follow-up after HA; however, only 9 patients in this cohort were treated for primary osteoarthritis. Studies consisting of largely heterogeneous cohorts,[6,9,11,19,21,23,35,39,48] coupled with predominantly single-center or single-surgeon data, limit the generalizability of the current literature.[3,11,20,29,30,34,39,41,42]

The role of shoulder arthroplasty for primary osteoarthritis in young patients is often reported in an older patient population than described in this study.[10,23,26,48] Edwards et al[10] reported results of a large group of patients treated with shoulder arthroplasty for primary osteoarthritis; however, the mean age was 67.2 years with a range of 42-90 years. Studies by Rispoli et al[30] and Wirth et al[48] also have similar patient demographics. Unlike the aforementioned studies, our study consists of only young patients (below 60 years of age) treated for primary osteoarthritis with shoulder arthroplasty.

Patients in our study demonstrated significant improvement in pain and functional outcome scores at mid-term to long-term follow-up. Both the HA and TSA groups had significantly improved ROM across nearly all parameters, which is consistent with previously reported literature.[10,19,20,26,31] Both HA and TSA also resulted in significant improvements in pain and Constant score.[37] Similar to other authors,[5,14,28,39] our study indicates significant differences in ROM, Constant score, and pain favoring TSA. Moreover, although the mean SSV at the final follow-up favored TSA, this was not significantly different compared with HA.

Rates of complications after shoulder arthroplasty in the young patient have raised notable concerns and have been reported to be as high as 46.2%.[3,8,10,19,31,41,42,45] In our study, 26.7% of shoulders treated with TSA had at least 1 complication, with the majority of the complications relating to the glenoid. Similarly, 29% of shoulders undergoing HA had at least 1 complication, with progressive glenoid wear being the most common complication.

The most significant concern regarding shoulder arthroplasty in young patients pertains to implant longevity and subsequent need for revision surgery. Younger patients are likely to have increased life expectancy and higher demands on the prosthesis secondary to increased activity level after shoulder arthroplasty.[23,35,50] Underlying etiology[42] and younger patient age[9,30,45] have been associated with higher revision rates in this population. Our study demonstrated that the vast majority of revision arthroplasty was performed for glenoid-related issues. Of the shoulders that underwent TSA and ultimately required revision surgery, 88% were attributed to glenoid failure. We also found that 80% of the patients with HA who ultimately required revision were revised for progressive glenoid erosion.

Revision arthroplasty secondary to glenoid wear or glenoid component failure is common and results in inferior outcomes compared with primary arthroplasty.[1,7,40] Dillon et al[9] demonstrated that 70% of revision arthroplasty in younger patients was due to glenoid failure; however, contrary to our findings, they reported a higher risk of revision with HA compared with TSA. Levine et al[20] reported that 29% of patients treated with HA required revision arthroplasty at long-term follow-up, compared with our HA revision rate of 16.1%. Denard et al[8] reported on a series of young patients treated with TSA for primary osteoarthritis and noted that 24% required revision for glenoid failure, which is similar to our rate of revision in this population.

In our series, earlier revision arthroplasty was observed among the HA group, whereas a more precipitous decline was observed later on among the TSA population. The majority of revision arthroplasty occurred by 5 years in the HA group compared with 15 years in the TSA group. The predominance of early revision in the HA group likely reflects the cohort of patients not satisfied with their early pain relief or clinical outcome after HA. Conversely, survivorship of TSA dropped fairly precipitously after 10 years of follow-up, likely reflecting symptomatic glenoid component loosening and failure. Overall, there was no significant difference in revision rate or survivorship between HA and TSA. Our survivorship data for TSA are similar to what is reported by Denard et al,[8] who reported 62.5% revision free survivorship in patients with TSA who were younger than 55 years with primary osteoarthritis. The results of this study are different than what has been reported by other studies consisting of heterogeneous patient cohorts with long-term follow-up.[3,34,41,42]

This study has several limitations. The retrospective nature of this study subjects it to possible bias. The information for this study was analyzed through a collective database, which relies on individual upkeep and data input. In addition, this study was a multicenter study, and therefore, it is possible that variations in operative techniques, implants, and postoperative protocols could have influenced the results. However, we feel that this lends insight to more generalizable results because it avoids the implicit bias that is inherent to studies performed by a single surgeon or single institution.

This study has numerous strengths. To the best of our knowledge, this series represents the largest cohort of entirely young patients undergoing shoulder arthroplasty for primary osteoarthritis. This study also benefits from having mid-term to long-term follow-up with a large number of patients, which adds strength to our survivorship analysis. In addition, our comparative analysis between patients undergoing HA and TSA provides a unique insight into a controversial and challenging topic. Furthermore, the multicenter nature of this study provides results that are more generalizable in comparison with series published by single surgeons or single institutions.

Conclusion

For young patients with primary glenohumeral osteoarthritis, both primary HA and TSA provide pain relief as well as significant subjective and clinical improvement at mid-term to long-term follow-up. TSA results in superior objective and patient-reported outcomes compared with HA. Patients undergoing HA tended to require earlier revision arthroplasty, whereas those undergoing TSA demonstrated a more precipitous decline in survivorship particularly after 10 years. Ultimately, we demonstrated no statistical difference in the rate of revision or the overall survivorship free from revision when comparing TSA with HA. The results of this study allow surgeons to best counsel young patients with primary glenohumeral osteoarthritis considering shoulder arthroplasty regarding the potential benefits and risk of requiring revision arthroplasty with either HA or TSA.

Disclaimer

Lionel Neyton is the paid consultant for and receives royalties from Wright, not related to this article. He is also the paid consultant for Arthrex. Philippe Collin is the paid consultant for and receives royalties from Tornier, not related to this article. He is also the paid consultant for Arthrex. Gilles Walch is the paid consultant for and receives royalties from Wright, related to this article. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Antuna SA, Sperling JW, Cofield RH, Rowland CM. Glenoid revision surgery after total shoulder arthroplasty. J Shoulder Elbow Surg 2001; 10:217-24.
2. Bailie DS, Llinas PJ, Ellenbecker TS. Cementless humeral resurfacing arthroplasty in active patients less than fifty-five years of age. J Bone Joint Surg Am 2008;90:110-7. https://doi.org/10.2106/JBJS.F.01552
3. Bartelt R, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in patients aged fifty-five years or younger with osteoarthritis. J Shoulder Elbow Surg 2011;20:123-30. https://doi.org/10.1016/j.jse.2010.05.006
4. Bercik MJ, Kruse K II, Yalizis M, Gauci MO, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elbow Surg 2016;25:1601-6. https://doi.org/10.1016/j.jse.2016.03.010
5. Bryant D, Litchfield R, Sandow M, Gartsman GM, Guyatt G, Kirkley A. A comparison of pain, strength, range of motion, and functional outcomes after hemiarthroplasty and total shoulder arthroplasty in patients with osteoarthritis of the shoulder. A systematic review and meta-analysis. J Bone Joint Surg Am 2005;87:1947-56. https://doi.org/10.2106/JBJS.D.02854
6. Burroughs PL, Gearen PF, Petty WR, Wright TW. Shoulder arthroplasty in the young patient. J Arthroplasty 2003;18:792-8.
7. Carroll RM, Izquierdo R, Vazquez M, Blaine TA, Levine WN, Bigliani LU. Conversion of painful hemiarthroplasty to total shoulder arthroplasty: long-term results. J Shoulder Elbow Surg 2004;13:599-603. https://doi.org/10.1016/j.jse.2004.03.016
8. Denard PJ, Raiss P, Sowa B, Walch G. Mid- to long-term follow-up of total shoulder arthroplasty using a keeled glenoid in young adults with primary glenohumeral arthritis. J Shoulder Elbow Surg 2013;22:894-900. https://doi.org/10.1016/j.jse.2012.09.016
9. Dillon MT, Inacio MC, Burke MF, Navarro RA, Yian EH. Shoulder arthroplasty in patients 59 years of age and younger. J Shoulder Elbow Surg 2013;22:1338-44. https://doi.org/10.1016/j.jse.2013.01.029
10. Edwards TB, Kadakia NR, Boulahia A, Kempf JF, Boileau P, Nemoz C, et al. A comparison of hemiarthroplasty and total shoulder arthroplasty in the treatment of primary glenohumeral osteoarthritis: results of a multicenter study. J Shoulder Elbow Surg 2003;12:207-13. https://doi.org/10.1016/S1058-2746(02)86804-5
11. Eichinger JK, Miller LR, Hartshorn T, Li X, Warner JJ, Higgins LD. Evaluation of satisfaction and durability after hemiarthroplasty and total shoulder arthroplasty in a cohort of patients aged 50 years or younger: an analysis of discordance of patient satisfaction and implant survival. J Shoulder Elbow Surg 2016;25:772-80. https://doi.org/10.1016/j.jse.2015.09.028
12. Ek ET, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: results after five to fifteen years. J Shoulder Elbow Surg 2013;22:1199-208. https://doi.org/10.1016/j.jse.2012.11.016
13. Fox TJ, Cil A, Sperling JW, Sanchez-Sotelo J, Schleck CD, Cofield RH. Survival of the glenoid component in shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:859-63. https://doi.org/10.1016/j.jse.2008.11.020
14. Gartsman GM, Roddey TS, Hammerman SM. Shoulder arthroplasty with or without resurfacing of the glenoid in patients who have osteoarthritis. J Bone Joint Surg Am 2000;82:26-34.
15. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717-21. https://doi.org/10.1016/j.jse.2007.02.123
16. Henn RF III, Ghomrawi H, Rutledge JR, Mazumdar M, Mancuso CA, Marx RG. Preoperative patient expectations of total shoulder arthroplasty. J Bone Joint Surg Am 2011;93:2110-5. https://doi.org/10.2106/JBJS.J.01114
17. Henry P, Razmjou H, Dwyer T, Slade Shantz JA, Holtby R. Relationship between probability of future shoulder arthroplasty and outcomes of arthroscopic debridement in patients with advanced osteoarthritis of glenohumeral joint. BMC Musculoskelet Disord 2015;16:280. https://doi.org/10.1186/s12891-015-0741-9
18. Krishnan SG, Reineck JR, Nowinski RJ, Harrison D, Burkhead WZ. Humeral hemiarthroplasty with biologic resurfacing of the glenoid for glenohumeral arthritis. Surgical technique. J Bone Joint Surg Am 2008;90(Suppl 2, Pt 1):9-19. https://doi.org/10.2106/JBJS.G.01220
19. Kusnezov N, Dunn JC, Parada SA, Kilcoyne K, Waterman BR. Clinical outcomes of anatomical total shoulder arthroplasty in a young, active population. Am J Orthop (Belle Mead NJ) 2016;45:E273-82.
20. Levine WN, Fischer CR, Nguyen D, Flatow EL, Ahmad CS, LU Bigliani. Long-term follow-up of shoulder hemiarthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 2012;94:e164. https://doi.org/10.2106/JBJS.K.00603

21. Levy JC, Virani NA, Frankle MA, Cuff D, Pupello DR, Hamelin JA. Young patients with shoulder chondrolysis following arthroscopic shoulder surgery treated with total shoulder arthroplasty. J Shoulder Elbow Surg 2008;17:380-8. https://doi.org/10.1016/j.jse.2007.11.004
22. Lo IK, Litchfield RB, Griffin S, Faber K, Patterson SD, Kirkley A. Quality-of-life outcome following hemiarthroplasty or total shoulder arthroplasty in patients with osteoarthritis. A prospective, randomized trial. J Bone Joint Surg Am 2005;87:2178-85. https://doi.org/10.2106/JBJS.D.02198
23. McCarty EC, Marx RG, Maerz D, Altchek D, Warren RF. Sports participation after shoulder replacement surgery. Am J Sports Med 2008;36:1577-81. https://doi.org/10.1177/0363546508317126
24. Millett PJ, Horan MP, Pennock AT, Rios D. Comprehensive Arthroscopic Management (CAM) procedure: clinical results of a joint-preserving arthroscopic treatment for young, active patients with advanced shoulder osteoarthritis. Arthroscopy 2013;29:440-8. https://doi.org/10.1016/j.arthro.2012.10.028
25. Molé D, Roche O, Riand N, Lévigne C, Walch G. Cemented Glenoid Component: Results in Osteoarthritis and Rheumatoid Arthritis. In: Walch G, Boileau P, editors. Shoulder Arthroplasty. Berlin: Springer; 1999. p. 163-71.
26. Norris TR, Iannotti JP. Functional outcome after shoulder arthroplasty for primary osteoarthritis: a multicenter study. J Shoulder Elbow Surg 2002;11:130-5. https://doi.org/10.1067/mse.2002.121146
27. Pritchett JW. Long-term results and patient satisfaction after shoulder resurfacing. J Shoulder Elbow Surg 2011;20:771-7. https://doi.org/10.1016/j.jse.2010.08.014
28. Radnay CS, Setter KJ, Chambers L, Levine WN, Bigliani LU, Ahmad CS. Total shoulder replacement compared with humeral head replacement for the treatment of primary glenohumeral osteoarthritis: a systematic review. J Shoulder Elbow Surg 2007;16:396-402. https://doi.org/10.1016/j.jse.2006.10.017
29. Raiss P, Aldinger PR, Kasten P, Rickert M, Loew M. Total shoulder replacement in young and middle-aged patients with glenohumeral osteoarthritis. J Bone Joint Surg Br 2008;90:764-9. https://doi.org/10.1302/0301-620X.90B6.20387
30. Rispoli DM, Sperling JW, Athwal GS, Schleck CD, Cofield RH. Humeral head replacement for the treatment of osteoarthritis. J Bone Joint Surg Am 2006;88:2637-44. https://doi.org/10.2106/JBJS.E.01383
31. Roberson TA, Bentley JC, Griscom JT, Kissenberth MJ, Tolan SJ, Hawkins RJ, et al. Outcomes of total shoulder arthroplasty in patients younger than 65 years: a systematic review. J Shoulder Elbow Surg 2017;26:1298-306. https://doi.org/10.1016/j.jse.2016.12.069
32. Rocourt MH, Radlinger L, Kalberer F, Sanavi S, Schmid NS, Leunig M, et al. Evaluation of intratester and intertester reliability of the Constant-Murley shoulder assessment. J Shoulder Elbow Surg 2008;17:364-9. https://doi.org/10.1016/j.jse.2007.06.024
33. Saltzman MD, Mercer DM, Warme WJ, Bertelsen AL, Matsen FA III. Comparison of patients undergoing primary shoulder arthroplasty before and after the age of fifty. J Bone Joint Surg Am 2010;92:42-7. https://doi.org/10.2106/JBJS.I.00071
34. Schoch B, Schleck C, Cofield RH, Sperling JW. Shoulder arthroplasty in patients younger than 50 years: minimum 20-year follow-up. J Shoulder Elbow Surg 2015;24:705-10. https://doi.org/10.1016/j.jse.2014.07.016
35. Schumann K, Flury MP, Schwyzer HK, Simmen BR, Drerup S, Goldhahn J. Sports activity after anatomical total shoulder arthroplasty. Am J Sports Med 2010;38:2097-105. https://doi.org/10.1177/0363546510371368
36. Sershon RA, Van Thiel GS, Lin EC, McGill KC, Cole BJ, Verma NN, et al. Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. J Shoulder Elbow Surg 2014;23:395-400. https://doi.org/10.1016/j.jse.2013.07.047
37. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. https://doi.org/10.1016/j.jse.2017.09.013
38. Skelley NW, Namdari S, Chamberlain AM, Keener JD, Galatz LM, Yamaguchi K. Arthroscopic debridement and capsular release for the treatment of shoulder osteoarthritis. Arthroscopy 2015;31:494-500. https://doi.org/10.1016/j.arthro.2014.08.025
39. Sowa B, Thierjung H, Bulhoff M, Loew M, Zeifang F, Bruckner T, et al. Functional results of hemi- and total shoulder arthroplasty according to diagnosis and patient age at surgery. Acta Orthop 2017;88:310-4. https://doi.org/10.1080/17453674.2017.1280656
40. Sperling JW, Cofield RH. Revision total shoulder arthroplasty for the treatment of glenoid arthrosis. J Bone Joint Surg Am 1998;80:860-7.
41. Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am 1998;80:464-73.
42. Sperling JW, Cofield RH, Rowland CM. Minimum fifteen-year follow-up of Neer hemiarthroplasty and total shoulder arthroplasty in patients aged fifty years or younger. J Shoulder Elbow Surg 2004;13:604-13. https://doi.org/10.1016/j.jse.2004.03.013
43. Strauss EJ, Verma NN, Salata MJ, McGill KC, Klifto C, Nicholson GP, et al. The high failure rate of biologic resurfacing of the glenoid in young patients with glenohumeral arthritis. J Shoulder Elbow Surg 2014;23:409-19. https://doi.org/10.1016/j.jse.2013.06.001
44. Triplet JJ, Everding NG, Levy JC, Moor MA. Functional internal rotation after shoulder arthroplasty: a comparison of anatomic and reverse shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:867-74. https://doi.org/10.1016/j.jse.2014.10.002
45. Wagner ER, Houdek MT, Schleck CD, Harmsen WS, Sánchez-Sotelo J, Cofield R, et al. The role age plays in the outcomes and complications of shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:1573-80. https://doi.org/10.1016/j.jse.2017.01.020
46. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756-60.
47. Wirth MA. Humeral head arthroplasty and meniscal allograft resurfacing of the glenoid. J Bone Joint Surg Am 2009;91:1109-19. https://doi.org/10.2106/JBJS.H.00677
48. Wirth MA, Tapscott RS, Southworth C, Rockwood CA Jr. Treatment of glenohumeral arthritis with a hemiarthroplasty: a minimum five-year follow-up outcome study. J Bone Joint Surg Am 2006;88:964-73. https://doi.org/10.2106/JBJS.D.03030
49. Wright TW, Flurin PH, Crosby L, Struk AM, Zuckerman JD. Total shoulder arthroplasty outcome for treatment of osteoarthritis: a multicenter study using a contemporary implant. Am J Orthop (Belle Mead NJ) 2015;44:523-6.
50. Zarkadas PC, Throckmorton TQ, Dahm DL, Sperling J, Schleck CD, Cofield R. Patient reported activities after shoulder replacement: total and hemiarthroplasty. J Shoulder Elbow Surg 2011;20:273-80. https://doi.org/10.1016/j.jse.2010.06.007