RESEARCH ARTICLE

Total Shoulder Arthroplasty is associated With Less Pain and Better Functional Outcomes, but Humeral Head Resurfacing may be Preferred in Younger, Higher Demand Patients: A Short-Term Outcomes Study in Patients with Glenohumeral Osteoarthritis

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Abstract

Objectives: This study aimed to compare short-term outcomes following Total Shoulder Arthroplasty (TSA) and Humeral Head Resurfacing (HHR) in patients with glenohumeral osteoarthritis (GHOA).

Methods: A retrospective analysis included patients who had undergone either TSA or HHR for GHOA at a single institution. Baseline demographics, complications, range of motion (active forward flexion, FF and active external rotation, ER), visual analog scores (VAS), and Subjective Shoulder Values (SSV) were collected.

Results: A total of 69 TSA and 56 HHR patients were analyzed. More HHR patients were laborers (44% versus 21%, P=0.01). There were more smokers in the TSA group (25% versus 11%, P=0.04) and more cardiovascular disease in the HHR cohort (64% versus. 6%, p<0.0001). Postoperative FF was similar, but ER was greater in the HHR (47° ± 15°) vs. TSA group (40° ± 12°, P = 0.01). VAS was lower after TSA vs. HHR (median 0, IQR 1 versus median 3.7, IQR 6.9, p<0.0001), and SSV was higher after TSA (89% ± 13% vs. 75% ± 20% after HHR; p<0.0001). Post-operative impingement was more common after HHR (32% vs. 3% for TSA, p<0.0001). All other complications were equivalent.

Conclusion: While younger patients and heavy laborers had improved ER following HHR, their pain relief was greater after TSA. Decisions on surgical technique should be based on patient-specific demographic and anatomic factors.

Level of evidence: III

Keywords: Humeral head resurfacing, Resurfacing hemiarthroplasty, Short-term follow-up, Shoulder osteoarthritis, Total shoulder arthroplasty

Introduction

Glenohumeral osteoarthritis (GHOA) is the third most common form of arthritis and affects up to one-third of those over the age of 60.[1,2] the prevalence of GHOA is projected to increase as the United States population ages. Risk factors for the development of GHOA include race, gender, weight, and genetic predisposition.[3] Occupation is also an important risk factor for GHOA, as manual laborers and those with jobs that require repetitive overhead motion are more likely to develop a painful, osteoarthritic shoulder.[3]

When the conservative management of GHOA fails, patients often resort to surgical management. While arthroscopy is the least invasive of these surgical options, the utility of arthroscopy in the treatment of GHOA is unsettled. While Millet et al[4] in their early outcome analysis reported increased functional scores and decreased pain

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scores after arthroscope, other cohort studies have been unable to replicate these favorable outcomes, with one retrospective analysis reporting that nearly 43% of patients required arthroplasty within 9 months of arthroscopy.[1,4-6] As the demand for shoulder arthroplasty continues to rise, with a projected increase of up to 750% by 2030,[7] it is imperative to identify indications for specific arthroplasty techniques to optimize longevity and outcomes.

Anatomic total shoulder arthroplasty (TSA) is generally considered the gold standard for managing GHOA, with excellent medium- and long-term results.[4,8,9] However, known complications of traditional stemmed TSA include glenohumeral instability, glenoid component loosening, rotator cuff dysfunction, and periprosthetic fracture.[10] Complication rates after TSA range from 10-16%.[10-12] Failed stemmed TSAs may be difficult to revise due to the challenge of removing and revising a stemmed humeral implant without compromising the patient's remaining proximal humeral bone stock.[13]

Humeral head resurfacing (HHR) is an alternative to TSA that has recently been shown to improve the function and pain of patients with GHOA.[14] While HHR is limited to cuff-intact shoulders with no little to no evidence of post-traumatic arthritis, advantages include a less extensive dissection, easier implantation, and preservation of humeral bone stock.[14,15] HHR may be particularly useful in young laborers and athletes as it preserves the patient's native shoulder girdle geometry and bone stock, thereby avoiding concern for early glenoid loosening in these challenging cohorts.

Few prior works have compared TSA and monopolar glenoid-preserving where TSA has largely been shown to yield superior return to sport, function, and patient satisfaction rates specifically over stemmed hemiarthroplasty.[2,9,16] However, there is a lack of information in the literature comparing TSA to HHR. This work compared the short-term clinical outcomes of HHR and TSA in patients with bipolar shoulder disease. We hypothesized that TSA and HHR are fundamentally different procedures, with different intended surgical goals, degrees of dissection, and target recipients. We hypothesized that TSA would result in improved pain scores and better functional outcomes in patients with GHOA compared with HHR. Further, given the technical challenge of TSA and the limited "bail out" options for revision procedures beyond conversion to a reverse total shoulder prosthesis, we hypothesized that select younger and higher-demand hosts may benefit from an initial bone-sparing procedure such as HHR.

Materials and Methods

Study Design and Patient Selection

This study was an institutional review board-approved retrospective cross-sectional analysis of all HHRs and TSAs performed by the two senior surgeons (M.R and A.L) from 2008 to 2019 at a single academic institution. The HHR cohort included patients who underwent initial surgery between 2008 and 2013, while the TSA group included patients with index surgery between 2013 and 2019. One surgeon performed HHR for all patients with GHOA, while the other surgeon performed TSA. The inclusion dates of these cohorts reflected periods of focused patient-reported outcomes collection following that specific procedure.

All patients with end-stage glenohumeral arthritis who failed non-operative management and underwent either HHR or TSA during the study period with a minimum of 9 months of post-operative follow-up were included. Exclusion criteria were inflammatory arthropathy, irreparable rotator cuff tears, a prior bilateral or ipsilateral shoulder arthroplasty, a history of septic arthritis, or pre-operative brachial plexus dysfunction.

Data Collection

Retrospective data was obtained from the electronic medical record (EMR). Demographic data included gender, medical comorbidities, employment in manual labor (yes/no), height, weight, and BMI. Active forward flexion (FF) and external rotation (ER) after TSA were recorded from the patient's most recent post-operative appointment, while that after HHR was based on the patient's self-reported survey responses. Adverse events such as wound complications, aseptic loosening, implant subsidence, trauma/dislocation, subscapularis failure or avulsion, stiffness/capsulitis, glenoid wear, and rotator cuff dysfunction were recorded. Patient satisfaction was measured with the Subjective Shoulder Value (SSV) and Visual Analog Pain score (VAS), which have been previously validated in the assessment of pain and function after shoulder arthroplasty.[17.18] SSV is a single-item self-completed measure in which patients are asked to grade their shoulder as a percentage of an entirely normal shoulder, which would score 100%.

Due to limited reports of in-clinic outcomes specific to this cohort, two separate survey mailings were sent to all living patients in the HHR cohort. Surveys included a patient satisfaction and range of motion (ROM) questionnaire and were matched where possible with retrospective chart documentation. Those who did not initially respond were contacted over the phone. The TSA cohort had fully documented physical exams in all cases, so did not require survey collection.

Statistical Methods

An *a priori* power analysis was used to calculate the sample size needed to detect statistically significant differences in patient-reported outcomes between HHR and TSA. Based on previous literature,[19] an effect size of 0.55 was estimated. With a=0.05 at a power of 80%, the total required sample size was estimated to be 106 individuals.

Our primary outcome was shoulder function, represented by SSV. Secondary outcomes included pain, complication rates (including revision), and ROM in forward flexion and external rotation. Primary and secondary outcomes were measured via subgroup analysis. In the age subgroup analysis, the elderly cohort was defined as any individual age 65 or older, a cutoff that has been used in prior studies.[20] in the laborer subgroup, the label "laborer" was reported by the individual patient when asked to identify their occupation and whether they identified as a laborer.

Patient demographics, satisfaction, and ROM were presented as mean +/- standard deviation (SD), median (interquartile range, IQR), and frequencies and percentages as indicated. Continuous variables were compared between groups using a two-sample, two-sided t-test or Mann-Whitney U-test, and categorical variables were tested with the chi-squared or Fisher's exact test. All analyses were performed using SAS Software (SAS Institute Inc, version 9.4, Cary, NC, USA). A p-value <0.05 was considered statistically significant.

Study Cohort

A total of 258 TSA and 357 HHR procedures were performed during the study period. After applying our exclusion criteria and removing patients with incomplete follow-up or outcome data, 125 total patients (69 TSA and 56 HHR) were available for analysis. The mean follow-up was 2.1 ± 1.4 years after TSA (range 1.0 - 5.6 years) and 1.8 ± 1.2 years after HHR (range 1.0 -6.1 years) (*P*=0.22).

There were no significant differences between the age (TSA range 47 – 89 years; HHR range 39 – 83 years), gender, or BMI of the patients who underwent TSA or HHR. More patients were manual laborers in the HHR group (44% versus 21% for TSA; *P*=0.01). The proportion of diabetics was similar between the TSA and HHR groups (24% versus 11% respectively; *P*=0.06). A larger number of HHR patients had cardiac comorbidities (coronary artery disease, heart failure, atrial fibrillation, or symptomatic heart valve conditions) compared with TSA patients (64% versus 6%, respectively; p<0.0001). More TSA patients smoked (25% versus 11% for HHR, *P*=0.04) [Table 1].

Table 1. Baseline Patient Demographics

	HHR (N = 56)	TSA (N = 69)	p-value
Age (years)	63.5 (9.8)	65.5 (8.7)	0.23
BMI (kg/m2)	29.4 (4.8)	30.7 (5.5)	0.15
Follow up years	1.8 (1.2)	2.1 (1.4)	0.22
Gender (% female)	19 (34%))	27 (39%)	0.55
Heavy Labor (%yes)	20 (44%)	11 (21%)	0.01
Smoke (%yes)	6 (11%)	17 (25%)	0.04
Cardiovascular Disease (%yes)	36 (64%)	4 (6%)	<0.0001
Diabetes Mellitus (%yes)	6 (11%)	16 (24%)	0.06

HHR = Humeral head resurfacing; TSA = total shoulder arthroplasty; BMI = body mass index. Continuous variables represented as mean (standard deviation), categorical variables represented as number (percentage); heavy laborers – 45 HHR responses, 53 TSA responses; smoker – 68 TSA responses; diabetes mellitus – 68 TSA responses. Bolded values denote significant p-value (<0.05)

Results

Overall Cohort

With regard to the overall cohorts, mean active FF was similar between groups, but active ER was greater in the HHR group (47° ± 15°) compared with the TSA group (40° ± 12°, P=0.01). The TSA cohort had a median VAS of 0 (IQR 1) compared with 3.7 (IQR 6.9) after HHR (p<0.0001). TSA patients reported higher SSV (89% ± 130%) compared with HHR patients (75% ± 20%, p<0.0001) [Table 2].

Table 2. Postoperative outcomes in all patients

	HHR		TSA		
	N	Mean (SD)	N	Mean (SD)	p-value
SSV (%)	54	75.2 (20.4)	61	89.2 (12.9)	<0.0001
VAS*	55	Median (IQR): 3.7 (6.9)	64	Median (IQR): 0 (1)	<0.0001
Active FF (degrees)	54	150.8 (27.0)	69	144.6 (23.0)	0.17
Active ER (degrees)	50	47.0 (15.1)	63	40.2 (11.9)	0.01

HHR = Humeral head resurfacing; TSA = total shoulder arthroplasty; SSV = Subjective shoulder value; VAS = visual analogue scale; FF = forward flexion; ER = external rotation; SD = standard deviation.
Data represented as number included in analysis (N) and mean (standard deviation). Bolded values denote significant p-value (p<0.05).
*Mann-Whitney U test was used

Postoperative complication rates were higher in the HHR group (36%) compared with the TSA group (16%, *P* = 0.01). Impingement complaints were frequently more common after HHR (32% vs. 3% after TSA, p<0.0001). Reoperation/revision rates were similar between groups [Table 3].

Subgroup Analysis: Young Patients

When analyzing younger patients (<65 years), the TSA group had a mean age of 58.9 ± 4.6 years (range 47-64 years) while the HHR group had a mean age of 56.1 ± 7.3 years (range 39-64 years) (p=0.0629). Younger patients who underwent TSA had higher SSV (89% ± 13% after TSA versus 78% ± 17% after HHR, P=0.0046) and lower VAS scores at final follow-up (median 0, IQR 2 after TSA versus median 5, IQR 6.7 after HHR, p< 0.0001). Active FF was equivalent between groups, although active ER was greater after HHR (49° ± 13°) compared with TSA (38° ± 12°, P = 0.001) [Table 3]. SSV was higher after TSA in older patients (90% ± 13% vs. 73% ± 24%, P = 0.002), and VAS was lower (median 0, IQR 0 after TSA versus median 3.25, IQR 7.2 after HHR, P<0.0001). The range of motion was equivalent between these groups [Table 4]. Finally, there was a greater proportion of complications amongst young patients who underwent HHR compared to TSA (46.4% vs 10.8%, P=0.001).

Table 3. Postoperative outcomes in younger patients, defined as < 65 years of age

	HHR		TSA		
	N	**Mean (SD)**	**N**	**Mean (SD)**	**p-value**
SSV (%)	27	77.7 (16.6)	32	88.9 (12.6)	0.0046
VAS*	27	Median (IQR): 5 (6.7)	37	Median (IQR): 0 (2)	<0.0001
Active FF (degrees)	28	153.9 (25.9)	37	146.8 (15.6)	0.2
Active ER (degrees)	25	49.4 (13.3)	36	38.3 (11.6)	0.001
Complications	28	46.4%	37	10.8%	0.001

HHR = Humeral head resurfacing; TSA = total shoulder arthroplasty; SSV = Subjective shoulder value; VAS = visual analogue scale; FF = forward flexion; ER = external rotation; SD = standard deviation. Data represented as number included in analysis (N) and mean (standard deviation). Bolded values denote significant p-value (p<0.05). *Mann-Whitney U test was used

Table 4. Postoperative outcomes in older patients, defined as ≥ 65 years of age

	HHR		TSA		
	N	**Mean (SD)**	**N**	**Mean (SD)**	**p-value**
SSV (%)	27	72.7 (23.7)	29	89.5 (13.4)	0.002
VAS*	28	Median (IQR): 3.25 (7.2)	27	Median (IQR): 0 (0)	0.001
Active FF (degrees)	26	147.5 (28.2)	32	142.2 (29.5)	0.49
Active ER (degrees)	25	44.6 (16.6)	27	42.6 (12.0)	0.62

HHR = Humeral head resurfacing; TSA = total shoulder arthroplasty; SSV = Subjective shoulder value; VAS = visual analogue scale; FF = forward flexion; ER = external rotation; SD = standard deviation. Data represented as number included in analysis (N) and mean (standard deviation). Bolded values denote significant p-value (p<0.05). *Mann-Whitney U test was used

Subgroup Analysis: Laborers

SSV was higher after TSA in heavy laborers (88% ± 15%) compared with HHR (73% ± 20%, P = 0.03), and VAS scores were lower (median 0, IQR 1 after TSA vs. median 3.25, IQR 6.5 after HHR, P=0.001). Active FF was equivalent between the two procedures in laborers, but laborers undergoing HHR had superior external rotation at final follow-up (48° ± 14° vs. 30° ± 10° after TSA, P = 0.001) [Table 5]. Finally, there was a greater proportion of complications amongst heavy laborers who underwent HHR compared to TSA (30.0% vs 12.5%, although this was not statistically significant (P=0.211).

Discussion

The most important finding of this study was that patients who underwent TSA had superior short-term function and pain scores compared with those who underwent HHR. However, such advantages were less significant in heavy laborers and younger patients. While this study's findings must be validated by subsequent higher-quality prospective analyses, we recommend that the decision to proceed with HHR over TSA be based on the individual patient's demographics and anatomic considerations.

While the literature comparing TSA and traditional stemmed hemiarthroplasty is robust, with superior functional outcomes and pain relief after TSA compared with HA,[21] works comparing TSA and HHR are limited by inconsistent outcomes reporting measurements and a lack of both randomization and prospective analyses. One systematic review compared the patient-reported outcomes of nearly 2000 patients who underwent TSA or HHR, reporting that those who underwent TSA had better pain relief and function compared with HHR. Patients who underwent HHR plus glenoid resurfacing versus isolated HHR had greater postoperative pain relief.[22] These findings support the theory that progressive glenoid wear is the predominant pain driver after HHR.[23] Unfortunately, we did not routinely obtain advanced imaging after TSA or HHR at > 1-year timepoints unless the patient developed significant pain in their shoulder. As glenoid wear is poorly identifiable using X-rays,[24] we are unable to report how many HHR patients had radiographic or clinically significant changes to their glenoid anatomy. Further studies aimed at evaluating the degree of progressive glenoid wear after HHR using routine advanced imaging may serve to identify those patients at risk of mid- and long-term revision and can further help characterize the pain discrepancy between HHR and TSA.

Table 5. Postoperative outcomes between heavy laborers

	HHR		TSA		
	N	**Mean (SD)**	**N**	**Mean (SD)**	**p-value**
SSV (%)	20	73.1 (20.3)	11	87.7 (14.5)	0.03
VAS*	20	Median (IQR): 3.25 (6.5)	11	Median (IQR): 0 (1)	0.002
Active FF (degrees)	18	148.1 (30.4)	11	143.6 (16.9)	0.23
Active ER (degrees)	16	47.8 (14.3)	11	29.5 (9.6)	0.001
Complications	20	30.0%	14	14.2%	0.211

HHR = Humeral head resurfacing; TSA = total shoulder arthroplasty; SSV = Subjective shoulder value; VAS = visual analogue scale; FF = forward flexion; ER = external rotation; SD = standard deviation. Data represented as number included in analysis (N) and mean (standard deviation).
Bolded values denote significant p-value (p<0.05). *Mann-Whitney U test was used

Forward flexion was equivalent after TSA, but HHR resulted in greater postoperative active ER. Current literature on the expected changes in the range of motion following TSA and hemiarthroplasty is mixed, with some works showing that TSA provides a superior range of motion[5,16,25] while others report equivalent outcomes.[26] This wide variation in the reported range of motion is likely due to the lack of patient randomization and the limited number of patients in any given analysis. Glenoid wear after HHR may also contribute to differences in ROM within this group. Apart from implant selection and surgical technique, medical comorbidities may be an important determinant of ROM after shoulder arthroplasty or resurfacing. Diabetes, obesity, and hypertension have been correlated with postoperative stiffness and reduced range of motion.[16,27,28] Competence of the rotator cuff structures after TSA and HHR is assumed but has not been quantitatively evaluated using advanced imaging. Incompetence of the subscapularis would permit increased external rotation at the expense of functional deficits that may or not be noticeable by the patient, especially at early time points. It is also possible that patient-perceived range of motion as reported on surveys after HHR is imprecise, as patients in more discomfort may be more likely to self-report a worse range of motion. A well-powered, standardized range of motion analysis must be accompanied by strength exams to fully understand the impact of HHR and TSA on shoulder mobility.

The results of this paper suggest the importance of approaching shoulder arthroplasty with an individualized, anatomic approach. For instance, in laborers with osteoarthritis without severe glenoid changes, HHR may provide more work utility due to greater functional movement. An additional advantage to younger, more active patients undergoing HHR is the preservation of glenoid and humeral bone stock, permitting the use of standard TSA prostheses rather than reverse TSA if the need for a revision arises.[29]

Another important consideration is the fate of TSA in younger patients. Although TSA is considered the gold standard for GHOA, previous studies have shown that younger patients have decreased range of motion, poor patient-reported outcomes, and higher revision rates.[30-32] These studies make a compelling argument that while TSA may be preferred in older patients with worse bone stock in whom pain relief may carry more weight than functionality, younger patients who have greater physical demands due to work or recreational pursuits may prefer HHR. Understanding the whole patient and their complaint, level of activity, and unique anatomy is crucial to selecting the right surgical technique.

There are several limitations to this study beyond those inherent to retrospective analyses. First, range of motion and strength outcomes were based on the recorded physical exam of the operating surgeon without blinding. These were not collected using a goniometer or dynamometer. In contrast, the HHR range of motion was self-reported via survey. The use of different methodologies for collecting post-operative outcome data can lead to reporting and recall bias. Post-operative data collected at post-operative follow-up appointments, as was the case in the TSA cohort, exposes the cohort to courtesy bias, while patients in the HHR cohort, who recorded post-operative outcomes via surveys, were not exposed to the same data collection conditions. Second, it is important to note that while some differences between groups achieved statistical significance, they may not be clinically significant. Third, HHR has largely fallen out of favor compared to TSA. It is therefore likely that the findings of the present work will have less of an impact on surgical decision-making. Lastly, the sample size of this study was limited due to the number of procedures performed by the surgeons at our institution and therefore may prevent the detection of significant differences in underpowered comparisons. Despite these limitations, this study provides novel insight into the comparative short-term clinical outcomes after TSA and HHR. Future studies with increased sample size, routine imaging and range of motion measurements, and longer-term follow-up are necessary to identify differences in the outcomes of these techniques over time and to identify specific populations that might benefit from an initial HHR.

Conclusion

At short-term follow-up, TSA provided patients with significantly lower pain and better subjective outcomes than HHR. Range of motion was also similar between both cohorts, with slightly improved active ER after HHR. Heavy laborers and younger patients undergoing HHR had greater postoperative external rotation compared with TSA, although outcomes were otherwise equivalent. Both procedures are safe and effective overall, suggesting that decisions on implant selection should be individualized based on the patient's demographics and anatomy.

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