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Outcomes of shoulder replacement in humeral head avascular necrosis

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Background: This retrospective review evaluated 25 patients with 29 shoulders treated with arthroplasty for humeral head avascular necrosis (HHAVN) between 2004 and 2015. We hypothesized that regardless of implant, radiographic stage, or etiology, patients would appreciate significant improvement in pain, range of motion, and shoulder functionality after surgical intervention.

Methods: Data were obtained by record review on all patients meeting inclusion criteria. Outcomes were evaluated using Simple Shoulder Test, Modified Constant Score, University of California Los Angeles Shoulder Rating Scale, and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form. The data were assessed by all patients and subcategories (treatment, avascular necrosis stage, and underlying cause).

Results: At a mean follow-up of 3.9 years (range, 1-8.5 years), all patients who underwent operative intervention for HHAVN showed statistically significant improvement in functionality measurements ($P < .01$). Patients who underwent total shoulder arthroplasty (TSA) noted higher median outcome scores and greater improvement in all scoring methods compared with their hemiarthroplasty counterparts. The high-stage disease shoulders showed similar trends over low-stage counterparts. The shoulders in the trauma causal group had the highest scores in 3 of 4 outcome measures and favorable change in all scoring methods. These differences were not statistically significant ($P > .05$). No revision arthroplasties were required. Minor complications (suture abscess and intraoperative calcar fracture requiring cabling) occurred in 2 TSA patients.

Conclusions: Our outcomes demonstrate that in the short- to midterm follow-up, TSA or hemiarthroplasty is a safe and equally effective treatment for patients diagnosed with HHAVN regardless of etiology and radiographic staging.

Level of evidence: Level III; Retrospective design; Treatment Study

Keywords: Humeral head; avascular necrosis; shoulder arthroplasty; hemiarthroplasty; outcomes; complications

Avascular necrosis (AVN) of the humeral head (HHAVN) is encountered less commonly than AVN of the femoral head. As a result, less literature exists on its history and management. The extent of necrosis in the humeral head factors into the ultimate decision for surgical intervention and can be staged radiographically using the Ficat and Arlet classification, modified by Cruess for the shoulder.[2] Direct relationships between

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the increase in necrotic stage and the percentage of patients who needed shoulder arthroplasty have been described.[5]

HHAVN has multiple etiologies, the most common being corticosteroid use, trauma, and sickle cell disease.[5] Outcomes of total shoulder arthroplasty (TSA) and hemiarthroplasty (HA) in patients with HHAVN of different etiologies individually have been documented.[2,3,7-10,12-14] Overall, they have shown a reduction in pain and an increase in range of motion (ROM) with shoulder arthroplasty. However, these studies are few and small in sample size, with the exception of a limited number of articles. In addition, they often fail to compare surgical outcomes between differing etiologic groups, with the sickle cell disease population in particular being under-represented.[7]

This study evaluated the outcomes of surgical intervention for HHAVN and determined the influence of implant selection, radiographic disease stage, and disease etiology. We hypothesized that regardless of above-mentioned factors patients, would appreciate significant increases in functional outcome scores.

Materials and methods

Patient population

This retrospective review evaluated all patients seen by the senior author (S.I.G.) at Medical College of Wisconsin/Froedtert Hospital between January 1, 2004, and September 30, 2015. The inclusion criteria for this study were a diagnosis of HHAVN, preoperative affected shoulder functionality assessments and radiographic imaging, surgical treatment with HA or TSA, and a minimum of 1-year clinical follow-up with outcome shoulder functionality assessments. Patients who did not meet these criteria were excluded.

The senior author performed 41 arthroplasty procedures between the study dates for HHAVN. There were 25 patients (11 men and 14 women) with 29 affected shoulders who underwent 19 hemiarthroplasties and 10 TSA and met inclusion criteria for the study. Fourteen patients completed their most recent outcome assessments by telephone. Implants used consisted of Tornier and DePuy products. Humeral components were all inserted by press-fit technique. When TSA components were implanted, all-polyethylene glenoids with peripheral cement were inserted.

Physical examination and outcome assessment

Baseline functionality scores were calculated preoperatively using a thorough physical examination (shoulder strength and ROM) and completed questionnaires. Shoulder functionality scores and questionnaires used to evaluate all patients included Simple Shoulder Test, the Constant Score modified for age and sex, the University of California Los Angeles Shoulder Rating Scale, and the American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment Form. Patients returned to clinic after surgery and were re-examined in the same fashion. Outcome scores were similarly calculated from the patients' most recent postoperative appointments. A telephone questionnaire was used to further assess Simple Shoulder Test, University of California Los Angeles Shoulder Rating Scale, and ASES scores for midterm clinical follow-up on patients who were not available for clinical/radiographic evaluation.

Radiographic evaluation

All patients underwent standardized radiographic imaging at their initial appointment. Magnetic resonance imaging was obtained when necessary to diagnose HHAVN in those without radiographic findings, evaluate the extent of necrosis, and rule out possible rotator cuff pathology. The extent of necrosis was staged by the senior author based on the Ficat and Arlet classification, modified by Cruess for the shoulder.[2] If patients were available for annual postoperative follow, x-ray images were obtained.

Treatment

Treatment plans were based on clinical and radiographic findings as well as patients' expectations of outcomes. All procedures were performed by the senior author. The decision to perform a TSA vs. HA was based on patient age and the extent of glenoid degenerative changes appreciated on plain radiographs, magnetic resonance imaging, and intraoperatively. As determined by the senior author's algorithm, patients aged younger than 45 years, Outerbridge stage 2 changes or greater of the glenoid, and intact rotator cuff received HA with "ream and run" arthroplasty of the glenoid. If less than Outerbridge stage 2, simple HA was performed. If older than age 45 and an intact rotator cuff, patients received a TSA.

Analysis

Statistical analysis was performed using IBM SPSS predictive analytics software (IBM, Armonk, NY, USA). Averages were used for whole HHAVN population values because enough data points were available to assume normal distribution. For the comparison groups, median values were used because the number of patients became too small to assume normal distribution. The 3 comparison groups—HA vs. TSA, high stage (Ficat 1-3) vs. low stage (Ficat 4-5), and underlying etiology—were evaluated for complication rates, need for additional treatment, and functionality scores. The Fisher exact test was used to compare 2 groups of binomial data, with the Pearson χ^2 test used for 3 or more groups of binomial data. The Wilcoxon sign ranked test was used to compare 2 groups of paired scale variables. The Mann-Whitney test was used to compare 2 unpaired groups of scale variables, with the Kruskal-Wallis test used for 3 or more unpaired scale variables.

Results

The 25 patients with 29 affected shoulders (19 hemiarthroplasties and 10 TSA) that met inclusion criteria were an average age at the time of treatment of 49.2 years (range, 16-77 years), and the average follow-up time was 3.9 years (range, 1-8.5 years). One shoulder was classified as stage 1, 3 as stage 2, 6 as stage 3, 16 as stage 4, and 3 as stage 5. The presumed etiology of HHAVN based on clinical history was sickle cell disease in 8 shoulders, corticosteroid use in 6, trauma in 6, and other/unknown in 9.

Table I Average functional scores for all patients meeting inclusion criteria before arthroplasty, after required healing time, and improvement with arthroplasty

Assessment	Arthroplasty for humeral head avascular necrosis				
	Sample size* (No.)	Preoperative score (average)	Outcome score (average)	Improvement score (average)	*P* value†
Simple Shoulder Test	21	3.7	9.1	5.3	<.01
Modified Constant score	19	42.0	74.6	32.6	<.01
UCLA Shoulder Rating Scale	25	12.5	25.0	12.5	<.01
ASES score	19	32.4	75.2	42.7	<.01

UCLA, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form

* Indicates the number of shoulders that completed each scoring method.

† The *P* values represent the significance of the difference in the improvement scores for each method

Table II Median shoulder functionality scores for hemiarthroplasty and total shoulder arthroplasty cohorts before surgery, after required healing time, and improvement with surgery

Assessment	Sample size*		Preoperative score (median)			Outcome score (median)			Change (median)		
	Hemi	TSA	Hemi	TSA	*P* value†	Hemi	TSA	*P* value†	Hemi	TSA	*P* value†
Simple Shoulder Test	13	8	4.0	2.0	.086	9.0	11.5	.222	4.0	7.5	.086
Modified Constant score	13	6	45.2	39.1	.188	66.3	88.0	.430	19.1	63.6	.161
UCLA Shoulder Rating Scale	17	8	12.0	11.5	.384	23.0	29.0	.661	12.0	16.5	.281
ASES score	13	6	31.0	33.4	.568	73.3	85.0	.236	25.0	55.8	.054

Hemi, hemiarthroplasty; *TSA*, total shoulder arthroplasty; *UCLA*, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

* Number of shoulders in each treatment group that qualified for the scoring method corresponding to that row.

† The *P* values represent the significance of the difference between the hemiarthroplasty and total shoulder arthroplasty groups. The *P* value for the difference between preoperative and outcome scores for each treatment group is not presented;

The average functionality score for all patients is recorded in Table I. Regardless of implant selection, Ficat score, or HHAVN etiology, the improvement score (the difference in outcome vs. preoperative scores) was significant in all 4 functionality scoring methods ($P < .01$ by Wilcoxon sign ranked test). Whereas other studies have noted high complication rates in the presence of HHAVN, we did not appreciate this in our series of patients.[1,13] None of the arthroplasties required a revision operation. There were no complications in the HA group. Perioperative complications occurred in 2 of the TSA shoulders: a suture abscess, treated conservatively with oral antibiotics, and an intraoperative fracture to the medial calcar during the implantation of a press-fit humeral component that required the immediate placement of a cable for support. The patient with the intraoperative calcar fracture subsequently went on to uneventful healing without change in postoperative protocol.

The median functionality scores for the 10 shoulders treated with TSA and 19 with HA are recorded in Table II. The TSA shoulders had higher median outcome scores and greater improvements in scores than the HA shoulders in all 4 scoring methods, but none of these differences were statistically significant ($P > .05$ by Mann-Whitney test).

Based on the Ficat and Arlet classification, 10 had low-stage disease (stage 1-3), and 19 had high-stage disease (stage 4-5). The median functionality scores for shoulders with high-stage and low-stage disease are recorded in Table III. The shoulders with high-stage disease trended towards higher outcome scores and greater improvements in all 4 scoring methods than the shoulders with low-stage disease; however, these differences were not significantly significant ($P > .05$ by the Mann-Whitney test). Of note, the intraoperative fracture occurred in the high-stage cohort. The extensive necrosis involving the calcar likely contributed to the fracture during implantation of the press-fit prosthesis.

The etiology of HHAVN in 9 of the shoulders was classified as "unknown/other" because the cause could not be effectively attributed to any one factor. Corticosteroid use was the underlying etiology of HHAVN in 6 shoulders, sickle cell disease in 8, and trauma in 6. The median shoulder functionality scores for each causal group are recorded in Table IV. Shoulders with post-traumatic HHAVN had the highest outcome score in 3 of the 4 methods and the greatest improvement score in all 4 scoring methods. Despite these differences, the HHAVN etiology had no statistically significant effect on functionality outcomes or improvements in all

Table III Median functional scores for low-stage (stage 1-3) and high-stage (stage 4-5) disease patients before arthroplasty, after required healing time, and improvement with arthroplasty

Assessment	Sample size*		Preoperative scores (median)			Outcome score (median)			Change (median)		
	Stage 1-3	Stage 4-5	Stage 1-3	Stage 4-5	*P* value†	Stage 1-3	Stage 4-5	*P* value†	Stage 1-3	Stage 4-5	*P* value†
Simple Shoulder Test	8	13	3.5	3.0	.742	9.5	9.0	.355	3.5	6.0	.342
Modified Constant score	7	12	45.0	43.2	.933	58.9	89.2	.076	13.9	53.5	.205
UCLA Shoulder Rating Scale	9	16	12.0	11.5	.512	21.0	28.5	.292	10.0	15.0	.294
ASES score	7	12	33.0	28.1	.422	65.0	84.2	.310	26.7	45.0	.176

UCLA, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

* Number of shoulders in each disease stage group that qualified for the scoring method corresponding to that row.

† The *P* values represent the significance of the difference between the low-stage and high-stage groups' preoperative score, outcome score, and improvement in score for the scoring method corresponding to each row. The *P* value for the difference between preoperative and outcome score for each disease stage cohort is not presented.

Table IV Median functional scores before arthroplasty, after required healing time, and improvement with arthroplasty grouped by humeral head avascular necrosis etiology

Assessment*	Trauma	Corticosteroid	Sickle cell	Other/unknown	*P* value†
Simple Shoulder Test					
Preoperative	3.0	2.5	5.0	5.5	.442
Outcome	11.0	8.5	7.5	9.5	.486
Improvement (sample size)	9.0 (5)	5.5 (4)	5.0 (6)	3.0 (6)	.189
Modified Constant score					
Preoperative	42.5	37.6	42.6	45.0	.929
Outcome	91.7	64.3	96.6	61.3	.19
Improvement (sample size)	62.9 (5)	19.1 (5)	54.0 (2)	17.5 (7)	.603
UCLA Shoulder Rating Scale					
Preoperative	13.0	12.0	11.5	11.0	.932
Outcome	29.0	21.0	25.0	23.0	.803
Improvement (sample size)	15.0 (5)	11.0 (5)	13.5 (6)	10.0 (9)	.774
ASES score					
Preoperative	35.0	26.2	27.3	39.2	.645
Outcome	85.8	48.3	84.2	69.2	.508
Improvement (sample size)	51.7 (4)	25.0 (3)	45.1 (6)	27.4 (6)	.599

UCLA, University of California Los Angeles; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

* The sample sizes in parentheses in the "Improvement" rows represent the number of patients in each etiologic group that qualified for the scoring method corresponding to that row.

† The *P* values represent the significance of the difference between the 4 etiologic groups' preoperative score, outcome score, and improvement in score for the scoring method corresponding to each row. The *P* value for the difference between the preoperative and outcome score for each etiologic cohort is not presented.

4 scoring methods ($P > .05$ calculated using the Kruskal-Wallis test). Of note, the intraoperative fracture occurred in the steroid cohort.

Discussion

At an average postoperative follow-up of 3.86 years, HA and TSA patients both showed significantly higher outcome scores compared with preoperative scores in all 4 functionality scoring methods (Table I). TSA was performed in patients with Outerbridge stage 2 or greater and HA in patients with less glenoid involvement, which should be taken into consideration when selecting the implant. Regardless, this lends further credence to existing literature in which several studies on HHAVN of different underlying etiologies have found significant improvements in shoulder functionality and pain when treated with arthroplasty.[3,6,8-13]

Franceschi et al[4] recently published a systematic review in which they identified 12 studies that met Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines and their inclusion criteria of adults managed surgically for HHAVN. This encompassed 382 shoulders in 309 patients. They concluded core decompression should be considered first in low-grade Ficat stages, with HA and TSA being reserved for high-grade stage. No conclusive statement was made on a preference for HA vs. TSA.[4]

Orfaly et al[9] found significant improvements in pain (66 to 18 on the visual analog scale) and function (36 to 81 on the ASES Shoulder Index) after arthroplasty ($P < .01$) along with improvements in ROM. Hattrup et al[6] surveyed 88 HHAVN patients, noting the ASES score improved with both HA and TSA, with no difference between the interventions ($P = .6$). In the largest HHAVN arthroplasty studies to date, Schoch et al[12,13] performed retrospective reviews in atraumatic (141 patients with 9.3-year mean follow-up) and post-traumatic (93 patients with 8.9-year mean follow-up) cohorts comparing outcomes between HA and TSA. Both studies noted significant improvements in pain and ROM in all patients ($P < .01$).[12,13]

The shoulders that underwent TSA trended toward both higher outcome scores and greater score improvements in all 4 scoring methods than the shoulders that underwent HA (Table II); however, these differences were not statistically significant ($P > .05$). Similar HHAVN studies have reported conflicting results suggesting better outcomes and greater score improvements with HA than with TSA; however, none showed statistical or clinical significance.[6,8,9]

Orfaly et al[9] reported HHAVN patients treated with HA had higher outcome ASES scores (82 vs. 78) and greater improvement in ASES score (45 vs. 44) than those treated with TSA. Similarly, the outcome ASES scores for HA reported by Hattrup and Cofield[6] were higher than those for TSA (63 vs 62), as were the improvements in ASES (69 for HA vs. 63 for TSA). In comparing HA vs. TSA outcomes, Schoch et al[12,13] noted the only significant difference was greater improvement in pain score in the post-traumatic TSA cohort, with both groups noting trends toward greater improvements in pain, internal/external rotation, and overall satisfaction favoring TSA. Clearly, more research is necessary to determine whether one of these surgical options is superior to the other in this clinical context.

The combined arthroplasty complication rate of 6.9% at a mean follow-up of 3.9 years in this study was on the lower end of the reported range from 5.9% (Raiss et al) to 32.3% (Hattrup and Cofield).[3,6,8,9,11-13] The intraoperative medial calcar fracture occurred in a patient with high-stage HHAVN due to corticosteroid use. In the Orfaly et al[9] prospective series of 21 consecutive shoulders for HHAVN of various etiologies, an intraoperative fracture occurred in a patient with steroid-dependent systemic lupus erythematosus when the press-fit humeral stem was implanted.[9] Similar to our patient, their patient went on to heal without a change in postoperative protocol. Schoch et al[12,13] noted 3 intraoperative fractures in the atraumatic series, but did not define which etiologic subcategory, and 6 intraoperative fractures in the post-traumatic series, all of which were associated with malunions. In a report that used PearlDiver data (PearlDiver, Colorado Springs, CO, USA), Burrus et al[1] found a statistically significant higher postoperative complication rate in the post-traumatic and steroid associated subgroups. There was a significantly increased risk for intraoperative fracture associated with steroid-induced HHAVN.[1] The senior author advises caution in the high-stage HHAVN secondary to corticosteroid use, because the calcar is likely more susceptible to intraoperative fracture when a press-fit stem is inserted.

No surgical revisions were required for the patients in our study. Mansat et al[8] also reported no surgical revisions at an average of 7 years postoperatively, whereas Orfaly et al[9] had only 1 surgical revision of a TSA at an average follow-up of 4.7 years. Conversely, Schoch et al[12,13] noted a 13.5% revision rate in the atraumatic series (9.3-year follow-up) and 15% in the post-traumatic series (8.9-year follow-up). Additional surgery was necessary in 19 shoulders (15%) in the Hattrup and Cofield[6] study (mean, 8.9 years). It is likely that longer-term follow-up trends toward higher revision rates.

None of the 4 scoring methods in our study showed significant differences in outcome or improvement scores between the high-stage and low-stage cohorts ($P > .05$; Table III). Mansat et al[8] similarly found no statistically significant difference in postoperative Constant scores between their patients with differing stages of HHAVN. One may conclude that arthroplasty at any stage of HHAVN can be efficacious.

Regarding the cohorts based on etiology, the shoulders in our trauma causal group trended toward higher outcome scores in 3 of the 4 scoring methods and greater improvement in all 4 scoring methods than the other 3 etiologic groups (Table IV). However, none of the differences were statistically significant in any of the 4 scoring methods ($P > .05$). Orfaly et al[9] found that although arthroplasty patients with HHAVN due to prior steroid use had lower outcome ASES scores than post-traumatic patients (mean, 78 vs. 82), they noted greater improvements scores (mean, 52 vs. 33). Alternatively, Hattrup and Cofield[5] reported significantly higher outcome ASES scores in the steroid group than in the trauma group (median, 72 vs. 60; $P = .017$). Similarly, Raiss et al[11] noted the nontraumatic cohort had significant improvement in abduction, power, and the Constant score.

In patients with sickle cell disease, Lau et al[7] reported lower outcomes and improvement in ASES scores than those reported in this study (median outcome: 42 vs. 84.20; improvement: 27 vs. 45.05). Of their 8 patients, 2 required revision operations within 5 years,[7] whereas none of the patients with sickle cell disease in our study have needed additional surgery at a median of 2.34 years postoperatively. Conversely, Feeley et al[3] noted trends toward higher outcome measures in the sickle cell cohort and attributed the lack of statistical significance to small numbers (n = 4). Of note, our sickle cell cohort managed with HA or TSA is the largest presented in a head-to-head evaluation of outcome scores. Which etiologic group may benefit greatest from arthroplasty is not clear, and due to inconsistencies between our findings and those in the literature, further evaluation is warranted.

Our current study has some limitations. It would appear that there are trends toward greater improvements in functionality scores in the shoulders that underwent TSA as well as greater improvements and higher outcome scores in shoulders with high-stage disease. A larger sample size may have

provided the power necessary to prove these trends to be statistically significant. In addition, patients were not randomized to HA vs. TSA because decision making was made based on intraoperative findings, as mentioned before. Despite these limitations, we did find a statistically significant difference of the HA and TSA postoperative outcome scores compared with their preoperative scoring ($P < .05$).

Conclusion

Our results support the efficacy and safety in the short-term to midterm follow-up of arthroplasty procedures in patients diagnosed with HHAVN. Patient factors, including radiographic stage of disease and HHAVN etiology, do not appear to have a significant effect on surgical outcomes. Improvements in pain, ROM, and functionality can be achieved with TSA or HA with low risk of complications or need for additional procedures.

Disclaimer

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