Outcomes After Shoulder Replacement Surgery in the Young Patient

How Do They Do and How Long Can We Expect Them to Last?

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KEYWORDS

• Shoulder arthroplasty • Young patients • Outcomes • Implant survival
• Ream and run • Resurfacing • Hemiarthroplasty • Total shoulder arthroplasty

KEY POINTS

- Young patients with glenohumeral arthritis present treatment challenges to shoulder surgeons, as there are no clear consensus recommendations to guide clinician management.
- Although total shoulder arthroplasty remains the "gold standard" in geriatric patients with osteoarthritis, concerns over placement of a glenoid component in young patients remain.
- Hemiarthroplasty without glenoid preparation, "ream and run," hemiarthroplasty with biologic glenoid resurfacing, and humeral head resurfacing have all been proposed as alternatives in the treatment of osteoarthritis in the young patient.
- Most of the arthroplasty options offered can provide improvements in both pain and function; however, there remain certain limitations to each procedure.

INTRODUCTION

Young patients with glenohumeral arthritis present specific challenges to shoulder surgeons. Instead of arbitrarily placing an age definition for "young," we instead define this after detailed discussion with the patient in which his or her age, comorbidities, activity level, and expectations are taken into account. The surgeon must use these patient factors along with the available literature to make appropriate

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recommendations regarding shoulder arthroplasty options. At this time, there exists no clear consensus recommendations to guide surgeons in this decision-making process. This is in contrast to geriatric patients with osteoarthritis (OA), in whom anatomic total shoulder arthroplasty (TSA) has shown to reliably provide pain relief and restore function with excellent long-term survivorship. However, concerns remain regarding implant longevity, especially with the placement of a prosthetic glenoid component in young patients. These concerns are valid, as young patients have higher activity levels, greater functional expectations, more complex pathology, and greater potential for revision shoulder arthroplasty in the future. This has led surgeons to explore other options besides TSA in the treatment of glenohumeral arthritis in young, active patients, including hemiarthroplasty (HA) without glenoid preparation, "ream and run," HA with biologic glenoid resurfacing, and humeral head resurfacing (HHR).

One of the concerns with glenoid placement is that younger patients not only have higher activity levels, but are more likely to participate in sporting events.[1] Schumann and colleagues[1] showed that the vast majority are able to continue participating in their respective sport after TSA as well. Younger patients also have increased expectations of TSA, as shown by Henn and colleagues.[2] In their study, multivariate analysis showed that younger age was the only independent predictor of greater expectations. Increased expectations may translate to increased motivation and better postoperative outcomes, but also are likely to generate increased demands seen by the prosthesis. This has the potential to accelerate polyethylene wear, which may contribute to an increased likelihood of glenoid wear and loosening (**Fig. 1**). As such, most shoulder surgeons place patients on permanent activity restrictions following shoulder arthroplasty. Surgeons are generally more restrictive after TSA than HA.[3] There remains considerable variation in long-term activity restrictions among surgeons, and in all likelihood, patients are likely to resume activities they feel comfortable with despite postoperative restrictions.

Another important point to consider for younger patients is the etiology of their shoulder pathology and the effect on long-term outcomes. Saltzman and colleagues[4] showed that only 21% of shoulder arthroplasties performed for patients younger than 50 were for OA as compared with 66% for patients older than 50. These other diagnoses, including rheumatoid arthritis (RA), avascular necrosis (AVN), chondrolysis, posttraumatic arthritis, and instability, have less predictable outcomes,

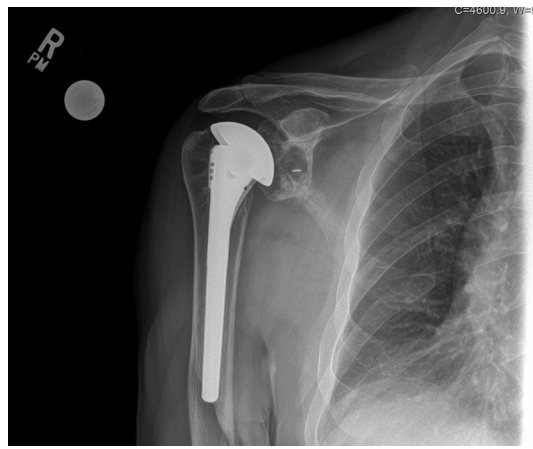

Fig. 1. Shoulder radiograph depicting glenoid component loosening.

making interpretation of TSA results in younger patients difficult. The culmination of younger age at implantation, increased activity level, and more difficult pathology makes the need for future revision surgery after TSA more likely. This has led surgeons to consider other options to TSA, as the glenoid component has historically been the "weak link" in shoulder arthroplasty and revisions for glenoid loosening and polyethylene wear are difficult and ultimately may preclude placement of another glenoid component.

Specifically, HA has been advocated by some, which negates some of the concerns revolving around activity restrictions and glenoid loosening. However, there are concerns over progression of glenoid arthrosis causing glenoid-sided failures and declines in long-term outcomes (**Fig. 2**).[5] Procedures involving biologic glenoid resurfacing with a number of graft sources were developed to limit glenoid attrition and arthrosis.[6,7] The results have been mixed, with some studies showing extremely high failure rates.[8] Another important consideration for HA is if the glenoid wear pattern is concentric or eccentric, as studies have shown inferior results for eccentric glenoid wear.[9] Matsen and colleagues[10] described their "ream and run" procedure, which establishes a concentric relationship and stimulates fibrocartilage growth by glenoid reaming. This has been best suited for motivated patients, as the early recovery period can be difficult and painful. Less talked about than the glenoid side, is the importance of preserving humeral bone stock by some, which can be accomplished by HHR. These surgical options have made it challenging to come up with a consensus for the treatment of shoulder arthritis for young patients.

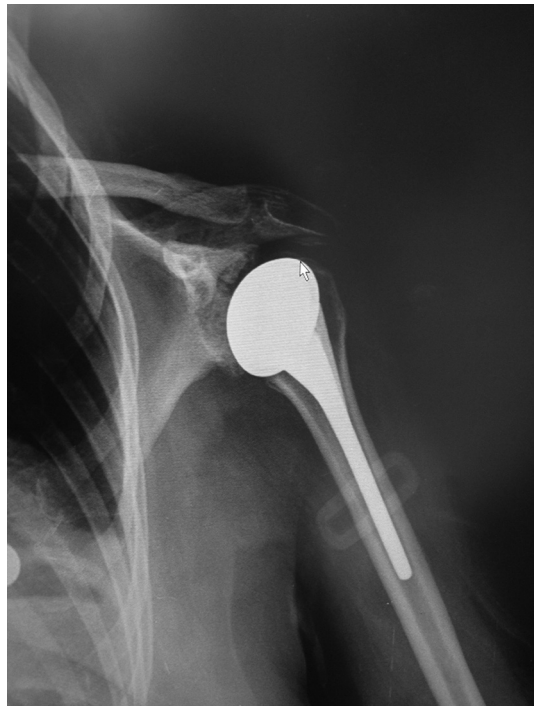

Fig. 2. Preoperative radiograph from a patient who underwent revision for painful glenoid arthrosis following hemiarthroplasty.

Glenohumeral arthritis in young patients is a complex and difficult clinical situation for shoulder surgeons that entails an in-depth discussion with each patient. The surgeon must be mindful that there is likely not one option for every patient. Here we examine the existing literature on the outcomes for the different arthroplasty options for young patients, hopefully allowing the surgeon to maximize clinical outcomes and revision-free implant survival.

TOTAL SHOULDER ARTHROPLASTY

The gold standard for the treatment of end-stage glenohumeral OA that has failed nonoperative management is TSA. The average patient age for patients undergoing TSA is 68.8 years, however, and the question remains if the same outcomes and implant longevity can be attained for younger patients.[11] Roberson and colleagues[12] performed a systematic review looking at the outcomes of TSA in patients younger than 65 years. A total of 6 studies were included in analysis. The average rates of revisions and complications were 17.4% and 9.4%, respectively, at an average of 9.4 years' follow-up. Overall rate of glenoid lucencies was 54%. The investigators concluded TSA can provide predictable pain relief and outcomes, but reported outcomes appear to be inferior to the TSA population as a whole. There are a few published reports on long-term follow-up after TSA in young patients. Denard and colleagues[13] retrospectively reviewed 50 patients who underwent a TSA for OA with a keeled glenoid component at 55 years or younger. At an average follow-up of 115.5 months, the age-adjusted Constant Score (CS) improved from 37.0% to 73.4%. Overall, survivorship of the glenoid component was 98% at 5 years, but unfortunately dropped to 62.5% at 10 years. Glenoid components were 6 times more likely to loosen if the humeral head was not anatomically positioned. Glenoid morphology had a significant effect on survival as well; the 10-year survival for concentric glenoids was 87.5% and eccentric glenoids was only 50%. Another study, from Sowa and colleagues,[14] examined the outcomes of 21 patients who had a TSA implanted before age 60 for OA. Overall, 2 patients were revised and 2 were recommended revision surgery for either rotator cuff (RTC) insufficiency or glenoid loosening. At an average of 13 years' follow-up, the average CS was 56.5 compared with 23.3 preoperatively, declining from 62.8 at midterm follow-up. Of the 19 patients without revision surgery, 18 were satisfied or very satisfied. Proximal migration was moderate or severe in 12 of the 19 patients, lending the need for surveillance long-term for RTC insufficiency/failure. Another study out of the Mayo Clinic reported survival rates for TSA of 83.2% at a minimum of 20-year follow-up. Of the TSA cohort, 53%, 9 of 17, humeral stems were at risk as well as 35%, 6 of 17, of glenoid components.[15]

With the concerns for RTC insufficiency or glenoid loosening leading to long-term failures, HA has been advocated as an alternative. There are multiple studies that have made direct comparisons between HA and TSA, and there are 3 randomized control trials (RCTs).[16–18] Sandow and colleagues[18] randomized 33 patients with OA to receive an HA or TSA and assessed them at a minimum of 10 years postoperatively. The study was terminated early due to significantly more pain in the HA group. The average visual analog scale (VAS) was 0.5 in the TSA group compared with 4.6 in the HA group at 2 years postoperative. At latest assessment, no patients with an HA were pain-free compared with 55% with a TSA. Overall 31% (4 of 13) of patients in HA group were revised compared with 10% (2 of 20) for the TSA group. Bryant and colleagues[19] conducted a systematic review and meta-analysis that included the 3 previously mentioned RCTs. At a minimum of 2-year follow-up, TSA resulted in better functional outcomes than HA for the treatment of OA. Edwards and colleagues[20]

conducted a multicenter retrospective study that was consistent with these results. A total of 601 TSAs and 89 HAs were performed for OA and followed for an average of 43.3 months. The TSA group had significantly better scores for pain, mobility, and activity, as well as overall and age-adjusted CS. The TSA group also had better forward elevation and external rotation. Interestingly, analysis of nonconcentric glenoid morphology also showed TSA outperformed HA. Kaplan-Meier survivability curve favored HA due to midterm failures of metal-backed glenoid components, however. These results are encouraging for TSA; however, both of these studies were conducted on geriatric patients, who do not have the same concerns as younger patients.

Several studies have specifically compared TSA with HA in younger patients.[21–23] Dillon and colleagues[21] conducted a retrospective cohort study of the Kaiser shoulder arthroplasty registry. A total of 504 (16.9%) of 2981 shoulder arthroplasties were performed in patients younger than 59 years. Younger patients had more than 2 times the risk of revision compared with older patients. When examining the younger cohort independently, the risk of revision following HA (Relative Risk = 2.20) or HHR (Relative Risk = 5.84) was significantly higher compared with TSA. This led the investigators to support the use of TSA in younger patients. Eichinger and colleagues[22] retrospectively reviewed patients younger than 50 years receiving an HA or TSA. The investigators found a failed outcome in 22% of HA compared with 7% for TSA. Also, both implant survival (89% vs 95%) and satisfaction (72% vs 95%) were inferior with HA compared with TSA. Last, Bartelt and colleagues[23] evaluated a total of 66 shoulder arthroplasties (46 TSA and 20 HAs) retrospectively, with a mean follow-up of 7 years. Implant survival was 100% at 5 years and 92% at 10 years for TSA compared with 85% and 72%, respectively, for HA. Patients receiving a TSA had higher satisfaction (87% vs 65%), greater forward elevation, and better pain relief. Glenoid erosion was seen in all HAs with 6 (46%) of 13 being moderate or severe.

As the health care environment continues to evolve, focus has been placed on providing high-quality and cost-effective health care. Questions remain on the most cost-effective strategy for management of shoulder arthritis in the young patient. Bhat and colleagues[24] conducted an economic analysis using a Markov decision tree and Monte Carlo simulation looking at patients aged 30 to 50 with shoulder OA. The simulation was carried to the age of 70. This analysis found TSA to be superior to HA in young patients. HA provided 11.29 quality-adjusted life years (QALY) gained compared with 16.29 QALY by TSA. Overall, HA resulted in 0.4 revisions per patient and TSA 0.3 per patient, resulting in direct reimbursements for HA totaling $25,000 versus $23,700 for TSA. Interestingly, even if the costs of TSA and HA were the same, the analysis would still favor TSA.

HEMIARTHROPLASTY WITHOUT GLENOID PREPARATION

As stated earlier, individual comparison studies between TSA and HA have favored TSA in the treatment of shoulder arthritis in young patients due to greater pain relief, increased outcomes, and lower revision rates. Many of these studies include only short-term follow-up of patients with a diagnosis of OA, which leaves unanswered the question of how continuous glenoid arthrosis in HA or glenoid loosening in TSA will have on the eventual long-term outcome. Clearly surgeons have hesitation with placing a glenoid component in younger patients, as highlighted by a study conducted by Griffin and colleagues.[25] The investigators used the Nationwide Inpatient Sample to analyze 58,790 patients undergoing TSA or HA between 2000 and 2008. Only 7.5% (4430 of 58,790) were younger than 50 years at the time of surgery. Surgeons greatly favored the use of HA, which was used 63.9% of the time. There are clinical situations,

such as AVN with unipolar changes and OA in young weightlifters or heavy laborers, in which the surgeons will lean toward the use of HA over TSA. In fact, much of the literature for HA in young patients has been for the diagnosis of AVN.[26–29] Feeley and colleagues[26] found, at an average mean follow-up of 4.8 years, no significant difference with range of motion (ROM) or outcomes between TSA and HA, but TSA was associated with significantly more complications (22% vs 8%). The largest study of shoulder arthroplasty for AVN was conducted by Hattrup and Cofield,[29] with a total of 127 shoulders. At average of 7.9 years of follow-up, the mean American Shoulder and Elbow Surgeons (ASES) score was 63 for HA and 62 for TSA. There was no difference in ROM or rates of revision as well. Overall, 3 patients required conversion to TSA for painful glenoid arthrosis, and 1 patient required revision for glenoid loosening. Using Kaplan-Meier Survivorship curve, radiographic failure rates for TSA were 28% at 5 years and 38.3% at 10 years.

Much of the long-term survival and outcomes data for HA use in young patients comes from 2 studies out of the Mayo Clinic.[15,30] The estimated 10-year, 15-year, and 20-year HA implant survival rates were 82%, 75%, and 75%. At 15-year and 20-year follow-up, HA resulted in a satisfactory Neer rating in only 40% and 27% of patients, respectively. Overall, 20 (26.6%) of the original 75 patients receiving an HA required a revision before the 20-year follow-up mark, with 64% (16 of 20) of these being for painful glenoid arthrosis. Of these patients, all but one was able to be converted to a TSA. A satisfactory result after conversion of a failed HA to TSA is difficult and unpredictable. Carroll and colleagues[31] looked at 16 consecutive patients who underwent revision TSA for failed HA with a mean follow-up of 5.5 years. The mean improvement in forward elevation (FE) was 50°, and external rotation (ER) was 27°, ASES was 73.6, and VAS was 2.4. Unfortunately, 7 (47%) of 15 had an unsatisfactory result. This was similar to the Sperling and Cofield[32] study in which 39% had an unsatisfactory result due to lack of ROM or need for revision.

Recently, pyrocarbon has been introduced to potentially decrease the rate of cartilage degeneration seen with conventional metallic-bearing surfaces and has promise for use in shoulder HA. Pyrocarbon is a manufactured material with portions of the 2-dimensioinal (2-D) structure of graphite and 3-D structure of diamond. It has favorable mechanical characteristics, as the elastic modulus is similar to bone, is wear resistant, and has a low coefficient of friction. In a study conducted on canine acetabulums, pyrocarbon resulted in lower levels of cartilage wear and subchondral bone changes as compared with metallic prosthesis.[33] Currently, pyrocarbon is being used in hand and radial head prosthesis with success.[34–36] Currently, there is an Investigational Device Exemption trial under way in the United States, which has generated excitement, but outcomes data are yet to become available (**Fig. 3**).

HUMERAL HEAD RESURFACING

HHR has been proposed as an alternative to HA, as it avoids an anatomic neck cut, thus preserving more proximal humeral bone stock. It also avoids stem placement, which becomes important in young patients who participate in sports, as this can lead to a higher risk for periprosthetic humeral shaft fractures. It is believed that by preserving more of the original anatomy, this would translate to greater ease in future revision shoulder arthroplasty. This is especially important, as younger patients are at greater risk of poorer outcomes and need for future revisions, as alluded to previously. However, there have been concerns regarding the ability of HHR to reliably reproduce the proximal humeral anatomy.[37]

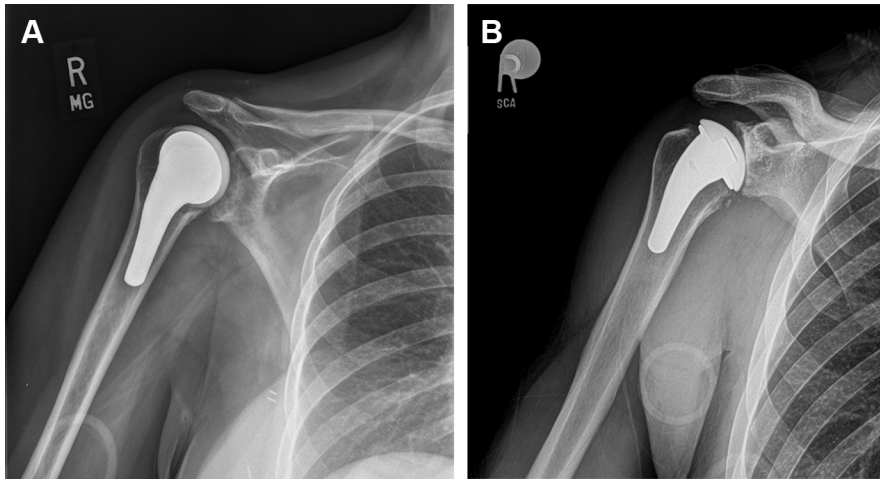

Fig. 3. Internal (*A*) and external (*B*) anteroposterior radiographs of a hemiarthroplasty with a pyrocarbon humeral head.

Mansat and colleagues[38] placed resurfacing shoulder implants in 61 patients (64 shoulders) and demonstrated that HHR reproduced the normal joint anatomy with a tendency to position prostheses in varus. In their observational case study, Alizadehkhaiyat and colleagues[39] found satisfactory HHR outcomes for patients with the mean age of 66.5 years and mean follow-up of 4 years. Overall, they found that resurfacing produced satisfactory (VAS scores <5) and unsatisfactory (VAS scores >5) results in 85.0% and 6.5% of patients, respectively. The investigators' best results were found in OA subgroup, with patients having a significantly higher CS (61 $\pm$ 21.3) than patients with RA (44 $\pm$ 20.5), the next largest patient group. These results were consistent with what was previously reported by Levy and Copeland,[40] Thomas and colleagues,[41] and Mullet and colleagues[42] with regard to patients older than 65.

Bailie and colleagues[43] studied and reported on the results of HHR in younger, more active patients (mean age 42.3 years) with a minimum of 2-year follow-up (mean follow-up of 38.1 months). VAS (7.5 vs 1.3), Single Assessment Numeric Evaluation (SANE) (24.7 vs 90.4), and ASES (29.8 vs 87.7) all improved significantly when comparing preoperative values with those at 2-year follow-up (P<.001). In addition, they did not appreciate any implant loosening during radiographic evaluation throughout the duration of the study. Although the investigators reported promising short-term HHR results in young patients, they did not compare these results with a control group (HA or TSA) to establish a proven benefit of HHR versus traditional treatment options for glenohumeral osteoarthritis. Anderl and colleagues[44] and Sweet and colleagues[45] have also illustrated similar short-term cementless surface replacement arthroplasty (CSRA) results in young patients.

Long-term follow-up results of HHR in young patients, until recently, has been limited. In 2015, Levy and colleagues[46] evaluated 54 HHRs performed on patients younger than 50 years and reported favorable symptomatic and functional results with a minimum of 10-year follow-up (mean follow-up 14.5 years). In their study, mean CS increased from 10.5 points to 62.0 points (P<.0001). Mean pain scores improved from 0.8 preoperatively to 13.8 at the most recent follow-up (P<.001). Moreover, the investigators also reported improvements in mean ROM from preoperative to most recent follow-up, with active FE increasing from 78° to 116°, ER improving from

13° to 51°, and internal rotation (IR) improving from 13° to 47°. Last, patient satisfaction scores at final follow-up were 8.7 of 10.0. Of note, 10 of the 54 shoulders (18.5%) required revision arthroplasty secondary to RTC failure (4), glenoid and reciprocal humeral loosening (4), glenoid erosion (1), and traumatic fracture (1).

The only RCT comparing stemmed HA with HHR has been performed by Rasmussen and colleagues.[47] Both arthroplasty options provided improvement in the Constant-Murley Score (CMS) and the Western Ontario Osteoarthritis of the Shoulder (WOOS) Index when comparing preoperative values with those at 1-year follow-up, but on average they found that HHR produced inferior results to those of stemmed HA at 1-year follow-up (mean difference in CMS of 3.9). This difference in mean improvement was statistically insignificant ($P = .58$), however, making it unclear whether a real difference existed between the 2 treatment models or if inherent differences were present in baseline patient characteristics. In their 2014 review of the Danish Shoulder Arthroplasty Registry, the investigators looked at all patients with OA who underwent HHR between January 2006 and December 2010.[48] Within this study period, 9.9% of 837 patients required revision by 5-year follow-up, similar to revision rates reported by the Norwegian Arthroplasty Registry, the New Zealand Joint Registry, and the National Joint Replacement Registry in Australia. It was determined that definite conclusions for these higher rates of revisions, when compared with stemmed HA outcomes, could not be made. Outcomes for those who underwent revisions (stemmed HA, reverse shoulder arthroplasty [RSA], or TSA) after failed HHR were largely suboptimal.[49] Thirty-three (41%) of the 80 cases available for follow-up had unacceptable outcomes (defined as a WOOS score of $\leq$50), indicating that revision cannot be relied on to correct failed HHR.

HUMERAL HEMIARTHROPLASTY WITH BIOLOGIC GLENOID RESURFACING

Previous attempts to solely replace the humeral head have proven to be inferior when compared with TSA in terms of ROM, function, and pain. The progression of glenoid arthrosis and wear can jeopardize the long-term outcome and ability to place a glenoid component in the future. Conversely, young patients with glenohumeral arthritis treated with TSA are at a higher risk for loosening and wear of the polyethylene glenoid component, causing concerns over the long-term durability. Combining humeral head replacement and glenoid resurfacing with biologic surfaces (anterior capsule, lateral meniscus, autogenous fascia lata, Achilles tendon allograft, and acellular dermal matrix) has been hypothesized to limit the glenoid attrition caused by HA alone and to avoid the premature failure of TSA implants in young patients.[6,7]

Two early reports showed favorable results for patients undergoing biologic resurfacing. Krishnan and colleagues[6] prospectively followed 36 shoulders that were treated with biologic glenoid resurfacing and HA (10 cemented, 26 uncemented). The mean ASES score was 39 points preoperatively and 91 points at the time of the most recent follow-up (minimum 2 years, mean 7 years, $P<.01$). Using the Neer criteria, the investigators found results of this procedure to be excellent for 18 shoulders (50%), satisfactory for 13 shoulders (36%), and unsatisfactory for 5 shoulders (14%). Pain scores decreased from 7.7 to 2.1 ($P<.03$) with 86% of shoulders having excellent (22 shoulders) or good (9 shoulders) pain relief. Finally, mean glenoid erosion was radiographically found to be 7.2 mm (range, 3–9 mm) and stabilized at 5 years postoperatively. Three of the 5 patients with unsatisfactory results used anterior capsule as the graft source and experienced increased pain and instability when compared with other graft sources. Similarly, Wirth[7] treated 30 shoulders with glenohumeral arthritis with HA and lateral meniscal allograft glenoid resurfacing and found

improved pain and ROM at a mean follow-up of 35 months. Mean active FE increased from 84° to 123° ($P<.001$), mean ER improved from 9° to 39° ($P<.001$), and mean IR improved by 2 vertebral segments. There was also a significant improvement of ASES, Simple Shoulder Test (SST), and VAS scores when comparing preoperative values. On radiographic examination, the investigators found the mean glenoid erosion to be 1.8 mm ($P<.001$).

Unfortunately, the early results of Krishan and colleagues and Wirth and colleagues have not been shown to be sustainable at mid to long-term follow-up. Multiple studies have shown that although patients undergoing HA with biologic glenoid resurfacing tend to have good clinical improvement, failure rates tend to be high in this patient population, leading to increased number of revisions at longer term follow-up.[8,50] Strauss and colleagues[8] evaluated outcomes of biologic glenoid resurfacing with lateral meniscal allograft and human acellular dermal matrix in 41 patients (mean age 42.2 years) with follow-up of 2.8 years. They found that at intermediate-term follow-up, the clinical failure rate was 51.2% overall. The lateral meniscal allograft group (31 patients) had a failure rate of 45.2% and a mean time to failure of 3.4 years, whereas the human acellular dermal matrix group (10 patients) had a failure rate of 70% with a mean time to failure of 2.2 years. Eight patients were revised to TSA or RSA. Despite these failure rates, clinical improvement was appreciated with mean increases in ASES scores from 36.8 to 62.0 ($P<.05$), improvement of SST from 4.0 to 7.0 ($P<.05$), and VAS decreasing from 6.3 to 3.0 ($P<.05$).

In a smaller study, Elhassan and colleagues[50] investigated 13 patients (average age 34 years) who had HA with biologic glenoid resurfacing (11 Achilles tendon, 1 fascia lata, 1 anterior capsule) completed to treat glenohumeral arthritis. Minimum follow-up was 2 years or until failure with a mean follow-up of 48 months. The investigators did not find any significant improvement in CMS, VAS scores, or Subjective Shoulder Values. Additionally, 11 of the 13 patients had persistent severe pain with radiographic evidence of graft failure and evidence of complete loss of the joint space by the time of the most recent follow-up. De Beer and colleagues[51] (28% failure rate), Puskas and colleagues[52] (63.6% failure rate), and Lee and colleagues[53] (56% failure rate) all have reported clinical outcomes similar to the 2 studies outlined previously. Interestingly, in a retrospective review of surface replacement hemiarthroplasty with biologic resurfacing of the glenoid, Lo and colleagues[54] assessed 18 shoulders (average age 54.8 years) with a mean follow-up of 4.8 years. Subjectively, 17 (94%) of the patients claimed to want to undergo the procedure again and 15 (83%) of the patients rated themselves as very satisfied or satisfied. Sixteen of the shoulders had radiographic follow-up with the mean time to follow-up of 5.1 years. The investigators did not notice any loosening of the prosthesis, but did find mild glenoid erosion in 6 cases, moderate in 6 cases, and severe in 3 cases.

One RCT aimed to compare biologic glenoid resurfacing with other treatment modalities. Hammond and colleagues[55] studied 44 patients (23 HA alone and 21 HA with biological glenoid resurfacing) aged 50 years or younger with a mean follow-up of 3.8 years for those undergoing HA and 3.6 years for those undergoing HA with biologic resurfacing. Clinically, the HA group had significantly lower VAS scores (1.8 ± 3.8 vs 4.8 ± 2.2; $P = .002$) compared with the biologic resurfacing group and significantly greater SANE scores as well (77.5 ± 22.9 vs 54.5 ± 21.7; $P = .024$). There was no significant difference in ASES scores, SST scores, CMS scores, or ROM between the 2 groups. As noted in previous literature, there was a high failure rate, defined as an ASES score less than 50 or need for revision, with the biologic resurfacing group (57.1%). Overall, the HA group had both improved clinical outcomes and lower rates of failure in comparison with the biologic resurfacing group.

REAM AND RUN

Glenoid morphology, such as glenoid retroversion and glenoid biconcavity, as well as humeral head posterior subluxation have been shown to increase the risk of glenoid loosening and clinical failures in TSA as well as HA.[5,9,56] These changes decrease the amount of available glenoid bone stock not only making glenoid component fixation during TSA difficult, but if left uncorrected, can lead to eccentric glenoid loading, increased wear, and persistent posterior subluxation of the humeral head. This triad presents a complex clinical challenge for shoulder surgeons, especially in young patients. "Ream and run" is an arthroplasty procedure described by Matsen and colleagues[10] that uses a traditional humeral prosthesis with concentric reaming of the glenoid. The radius of curvature of glenoid reaming is slightly larger than that of the humeral head, providing a concentric articulation, as well as stimulating fibrocartilage growth on the glenoid surface. The goal is not to completely correct glenoid retroversion, allowing preservation of glenoid bone stock, as well as allowing a more durable surface from the fibrocartilage stimulation (**Fig. 4**).

Matsen and colleagues[57] studied the ream and run procedure in 30 shoulders (average age of 56 years) with a mean follow-up of 3 years. They demonstrated that the procedure adequately improved the centering of the humeral head on the glenoid (75% posterior subluxation preoperatively vs 59% postoperatively, a mean difference of 16%, $P<.001$) without drastically changing glenoid retroversion. Subjective patient outcomes were also improved, with mean SST scores increasing from preoperative values of 5 ± 3 to postoperative values of 10 ± 4 (mean difference of 5, $P<.001$). Only 2 of the 30 shoulders underwent revision surgery and both had a history of instability repairs.

Saltzman and colleagues[58] produced similar results in a larger study when investigating 65 shoulders in patients aged 55 years or younger who underwent ream and run with a minimum follow-up of 2 years. SST scores increased from a mean of 4.1 before surgery to a mean of 9.5 at an average follow-up of 43 months ($P<.001$). Twenty-two of the shoulders had radiographic follow-up and showed an average medial glenoid

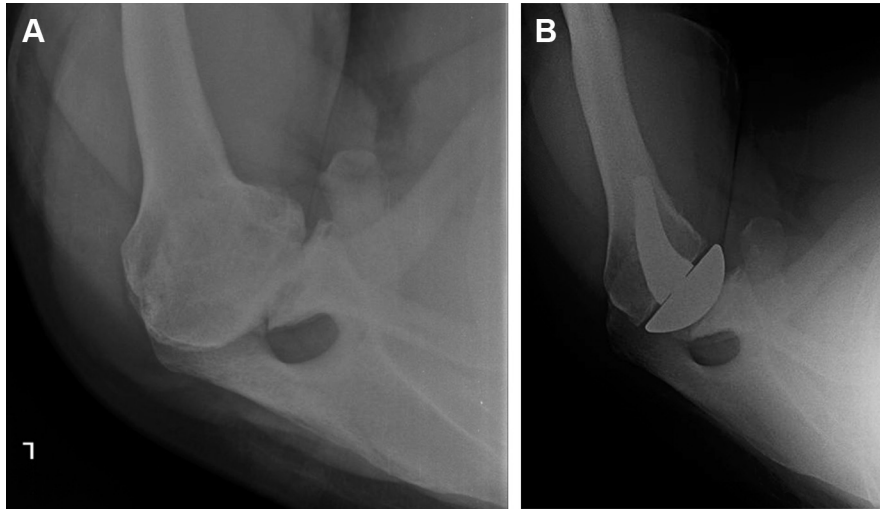

Fig. 4. Preoperative (*A*) and postoperative (*B*) axillary lateral radiographs showing a concentric glenohumeral articulation following "ream and run."

erosion of 1.1 mm at a mean follow-up of 44 months. Nine of the shoulders did require revision surgery, but these patients had on average 3 prior surgeries when compared with only 1 prior surgery for the nonrevised group. These results were reproduced at short-term and midterm follow-up by both Lynch and colleagues[59] and Somerson and Wirth.[60]

One published study aimed to characterize prognostic factors that would estimate improvement of shoulder function, as well as comfort and course of recovery for patients undergoing the "ream and run" procedure. Gilmer and colleagues[61] found that shoulder function and comfort progressively increased after this procedure, with patients reaching a steady state of each by 20 months. Factors that affected both quality of improvement and time course for return to function included patient age, sex, diagnosis, preoperative SST, and the number of prior surgical procedures. These factors are consistent with the ones previously reported for TSA. The investigators found that the patients with the best prognosis after the ream and run procedure were men older than 60 years with preoperative SST scores greater than 5, whose primary diagnosis was degenerative joint disease, and who had not had any previous surgeries.

In their 2007 case-matched-control study, Clinton and colleagues[62] compared functional outcomes between the ream and run procedure and TSA. Thirty-five consecutive patients (average age of 56 years) undergoing ream and run were compared with matched controls having TSA. The investigators found that mean SST scores for ream and run were 4.5 before surgery (vs 4.0 for TSA), 7.8 at 12 months (vs 9.6 for TSA), 8.3 at 18 months (vs 10.2 for TSA), 8.9 at 24 months (vs 9.4 for TSA), and 9.5 at 36 months (vs 10.0 for TSA). Ultimately, they concluded that ream and run can reliably produce similar functional results offered by TSA in the treatment of glenohumeral arthritis, albeit with more difficult and slower recovery times. Patients should be counseled regarding the more difficult recovery this procedure entails, as well as the risk of early failure due to continued pain in the early postoperative period.

SUMMARY

Shoulder arthritis in young patients is a challenging problem to treat for shoulder surgeons. There appear to be no perfect arthroplasty options and instead relies on the surgeon to use all the available data as well as patient-specific characteristics to drive surgical treatment. Currently, we do not have an arthroplasty option that is able to provide reliable pain relief and improve outcomes, without the increased risk for revision surgery. TSA appears to be a viable option for most patients and can reliably offer good pain relief, satisfaction, and postoperative outcomes; however, this comes with the increased risk of glenoid wear and loosening. TSA has been shown to be both a superior and cost-effective option for the treatment of OA in young patients compared with HA. However, HA remains an alternative to TSA in patients who are unable or unwilling to have more stringent activity restrictions in the postoperative period as well as for certain pathologies, such as AVN with unipolar changes. It is clear that HA is not without glenoid-sided failures, as progressive and painful glenoid arthrosis has shown to affect long-term outcomes, just as glenoid loosening affects the outcomes of TSA. A study by Franta and colleagues[63] examined the characteristics of 282 unsatisfactory shoulder arthroplasties. Glenoid-sided problems represented the vast majority of failures for both TSA and HA, confirming this as the "weak link" in shoulder arthroplasty.

Pyrocarbon represents one future option that has the potential of decreasing glenoid erosion and painful glenoid arthrosis following HA. However, this is not currently available within the United States and there remain no published reports of

pyrocarbon HA in the literature. “Ream and run” seems to provide an option for patients with eccentric glenoid wear, excessive glenoid retroversion, and posterior humeral subluxation. This is important, as the clinical outcomes and implant survival appear to be lower in this subset of patients with TSA and conventional HA. With the available literature, HA with biologic glenoid resurfacing does not appear to be a viable option in young patients with shoulder arthritis due to the heterogeneity of reported outcomes and high clinical failure rate. Although the potential benefits of preserving proximal humeral bone stock and avoiding stem placement with HHR are intriguing in the younger population, the literature seems to point to inferior outcomes as compared with stemmed HA.

Younger patients are less likely to live with the functional limitations of end-stage shoulder arthritis and more likely to opt for surgical treatment. Although most surgical options we can offer patients today are able to deliver both improvements in pain and function, there remain certain aspects of each procedure making them advantageous to specific subsets of patients. This entails an often difficult and detailed discussion with each patient, and concessions made by both the surgeon and patient to maximize outcomes and implant longevity.

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