JSES International 5 (2021) 142–148

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

The modern use of the extended humeral head (cuff tear arthropathy) hemiarthroplasty

Tyler J. Smith, DO [a], Sarav S. Shah, MD [b], Justin W. Peterson, DO [b], Glen Ross, MD [b,*]

[a] Department of Orthopedic Surgery, Philadelphia College of Osteopathic Medicine, Philadelphia, PA, USA
[b] Department of Orthopedics & Sports Medicine, New England Baptist Hospital, Boston, MA, USA

A R T I C L E I N F O

Keywords:
Rotator cuff tear arthropathy
cuff tear arthropathy
hemiarthroplasty
extended humeral head hemiarthroplasty
CTA hemiarthroplasty
reverse shoulder arthroplasty
Seebauer classification

Level of evidence: Narrative Review

Today, the treatment of osteoarthritis in the rotator cuff–deficient population is largely dominated by reverse shoulder arthroplasty (RSA). Despite the popularity of and increased familiarity with this procedure, the complication rate of RSA remains significant. An extended humeral head hemiarthroplasty may provide a less invasive alternative for select patients with cuff tear arthropathy (CTA) and preserved glenohumeral active elevation. With the indications for reverse arthroplasty expanding to younger patients, there are concerns about the longevity of this implant, as well as the associated revision burden. In the setting of failed RSA, the bone stock available for glenosphere baseplate fixation can be inadequate for reimplantation. The treatment strategies for complex shoulder deformities and failed RSA are limited by patient-specific issues, such as anatomy and risk factors. In this review, we discuss the potential role of extended humeral head hemiarthroplasty (CTA hemiarthroplasty) as a primary surgical option in select patients (1) who have preserved elevation > 90°, (2) who have maintained stability (intact coracoacromial ligament), and (3) who desire to circumvent the complications associated with RSA. Furthermore, CTA hemiarthroplasty may be used for severe glenoid erosion, for a fragmented acromion, and in the revision setting for failed RSA aimed at a reliable salvage procedure.

The first description of rotator cuff tear arthropathy (CTA) dates back to 1853, and in 1983, Dr. Neer formulated the term.[2,33] Neer et al[33] described a pathologic cascade of both mechanical and "nutritional" factors that ultimately result in osteopenia, osseous erosion, and muscular imbalance of the shoulder. The term CTA represents a wide spectrum of pathology but typically features rotator cuff insufficiency, superior migration of the humeral head, and glenohumeral degenerative changes.[14] Today, the treatment of CTA is largely addressed by reverse shoulder arthroplasty (RSA), which accounts for nearly half of all shoulder arthroplasties performed today.[36] Despite the popularity and increased familiarity with this procedure, the complication rate of RSA remains concerning.[1,6,9,22,43] Zumstein et al[43] performed a systematic review of RSA and found the global rates of problems, complications, reoperations, and revisions to be 44%, 24%, 3.5%, and 10%, respectively. With the indications for reverse arthroplasty expanding to a larger group of patients, there are also concerns regarding the longevity of this implant and the associated revision burden.[15–17,23,30,43] In the setting of failed RSA, the bone stock available for glenosphere baseplate fixation may be inadequate for reimplantation.[23] In this review, we discuss the role of the CTA hemiarthroplasty both as a primary surgical option and in the revision or salvage setting.

Neer was among the first authors to describe the pathogenesis of CTA. Chronic full-thickness rotator cuff tears and/or rotator cuff atrophy lead to a loss of the normal muscular force coupling that occurs in the coronal and transverse planes of the shoulder.[39] The rotator cuff musculature, when intact, compresses the humeral head against the glenoid, and it is responsible for concentric rotation during range of motion. Over time, the loss of native shoulder mechanics results in unopposed deltoid firing, humeral head elevation, degenerative changes, and the formation of a fixed glenohumeral-acromial joint.[3,33] The humeral tuberosities become eroded and "femoralized" while the undersurface of the acromion is "acetabularized," resulting in a stable ball-and-socket articulation.[3,33] Biological factors associated with CTA include alterations in cartilage and joint fluid glycosaminoglycan content, changes in fluid pressure, and recurrent effusions.[33]

CTA is primarily seen in female individuals, typically in the seventh decade of life, with large or massive rotator cuff tears or

This narrative review is exempt from institutional review board approval.

* Corresponding author: Glen Ross, MD, Department of Orthopedics & Sports Medicine, New England Baptist Hospital, 125 Parker Hill Ave, Boston, MA 02120, USA.

E-mail address: Ross2ortho@aol.com (G. Ross).

https://doi.org/10.1016/j.jseint.2020.09.011

rotator cuff atrophy. Other risk factors include patients in whom the dominant extremity is affected, those with rheumatoid arthritis, those with crystalline arthropathy, those receiving anticoagulation, or those with bleeding dyscrasias.[14,33,41] The Seebauer classification describes the radiographic progression of CTA, which results in decentralization of the center of rotation, a loss of joint stability, glenoid erosion, and anterosuperior humeral head escape (Table I). In type IA, the head remains centered on the glenoid; in type IB, the head migrates medially in relation to the glenoid; in type IIA, the humeral head migrates superiorly but remains stabilized by the coracoacromial (CA) arch; and in type IIB, the CA arch is incompetent and the head experiences anterosuperior escape. Type IIB disease represents severe, end-stage disease. Over time, attritional destruction of the glenohumeral joint stability and nonphysiological mechanics result in pain, loss of function, and often, pseudoparalysis.[41]

Historical treatment

The use of shoulder arthroplasty remained rare until the development of the Neer I hemiarthroplasty in 1955. Neer[32] reported pain resolution in 11 of 12 patients with hemiarthroplasty after proximal humeral fractures. In 1974, Neer[31] expanded the use of his hemiarthroplasty to treatment of glenohumeral osteoarthritis, reporting excellent or satisfactory outcomes in 40 of 44 patients. Total shoulder arthroplasty (TSA) was implemented for the treatment of CTA in the 1970s. Authors hypothesized that the presence of a glenoid component may provide additional stability and prevent superior humeral migration. This was later shown to result in glenoid loading, as well as early loosening, known as the "rocking-horse phenomenon."[21] Attempts at constrained TSA designs were associated with high complication and failure rates.[20] Because of the poor outcomes of TSA in patients without a functional rotator cuff, Neer et al[31,33,34] and other authors[21] suggested hemiarthroplasty as the primary management for CTA. Shoulder hemiarthroplasty provided satisfactory improvement in pain; however, functional results were less predictable, with only modest improvements in strength and range of motion.[4,5,28,31,33,34] Other concerns with the use of traditional hemiarthroplasty in rotator cuff arthropathy are CA arch erosion and superior humeral escape.

Table I
Seebauer classification of cuff tear arthropathy, as described by Visotsky et al,[41] detailing degree of superior humeral migration and destabilization from center of rotation

IA: centered, stable
Minimal superior migration of HH
Intact anterior restraints
Dynamic joint stability
"Acetabularization" of CA arch with contained HH
"Femoralization" of HH
IB: centered, medialized
Minimal superior migration of HH
Intact anterior restraints
Compensated dynamic joint stability
Acetabularization of CA arch with contained HH
Femoralization of HH
Medial erosion of glenoid
IIA: decentered, limited stability
Superior migration of HH
Compromised anterior restraints
Insufficient dynamic joint stability
Acetabularization of CA arch with minimal containment of HH
Femoralization of HH
IIB: decentered, unstable
Superior migration of HH
Incompetent anterior restraints
Absent dynamic joint stabilization
No stabilization by CA arch
Femoralization of HH
Anterosuperior escape

HH, humeral head; *CA*, coracoacromial.

Reverse shoulder arthroplasty

Early reverse ball-and-socket designs were developed in the 1970s after surgeons recognized the complications of using TSA in CTA yet were not satisfied with the modest functional improvements seen with hemiarthroplasty.[20] The Grammont-style prosthesis was developed in the 1980s with 2 critical design concepts: (1) lowering the humerus and (2) medializing the center of rotation. These 2 factors create a biomechanical advantage of the deltoid by allowing greater deltoid tension, as well as functional strength, while reducing the torque of the glenosphere and the risk of loosening.[20] The Grammont prosthesis provided the foundation for current RSA designs. In 2014, RSA bypassed TSA as the most common form of shoulder arthroplasty, accounting for 46% of all cases.[36] RSA is indicated for all forms of stable and unstable CTA (including Seebauer type IIB disease), improves pain, restores function, and has a high patient satisfaction rate.[6,22,35] However, the complication rates of RSA remain high.[1,6,43] In addition, there are concerns regarding the use of RSA in younger patients and patients with glenohumeral bone stock deficiencies.[15,16] For these reasons, investigators have continued to explore other designs.

Design and technique: restoration of deltoid tension

The extended humeral head hemiarthroplasty, also known as the CTA hemiarthroplasty, was first described in 2004.[7,41] Surgeons noticed that traditional hemiarthroplasty provided reliable pain relief at rest but pain returned with abduction and external rotation owing to impingement of the humerus on the acromion. The CTA prosthesis was developed to increase the surface contact between bone and the oversized prosthesis, minimizing impingement and frictional forces. The design includes an oversized humeral head that covers the greater tuberosity of the humerus (Fig. 1).[7] In addition, a large medial offset increases the moment arm of the deltoid, reduces deltoid strain, and decreases acromiohumeral contact forces by 54%.[26]

Although the biomechanics of the CTA prosthesis reduces the risk of superior escape seen with traditional hemiarthroplasty, the CA arch and an intact subscapularis are restraints to prosthesis escape. In the setting of an intact CA ligament, the prosthesis works to restore tension in the deltoid. Over time, the prosthesis centers in the glenoid and in a remodeled CA arch, conforming to the prosthesis. There are several steps in the surgical technique performed to maximize the functional design and stability of the CTA hemiarthroplasty. A standard deltopectoral approach is used, and during dissection, the anterior soft-tissue structures, clavipectoral fascia, and CA ligament are preserved. The subscapularis muscle is identified and mobilized, and if the biceps tendon is present, we prefer to perform a tenotomy as it may contribute to anterior pain. Special attention is paid to the location of the humeral head resection. To restore tension in the deltoid, lost as a result of the superior migration, we prefer a resection at the lower anatomic neck. The height of the selected prosthesis is superior to the described anatomic landmarks used for traditional hemiarthroplasty.[40] In the revision setting or when landmarks are deficient, the Gothic arch sign may be used.[25] By use of sizing templates, the curvature of the resected humeral head is matched. The diameter of curvature of the humeral articular surface is measured so that the corresponding prosthetic humeral head may be used. Deltoid tension may also be affected by the presence of a

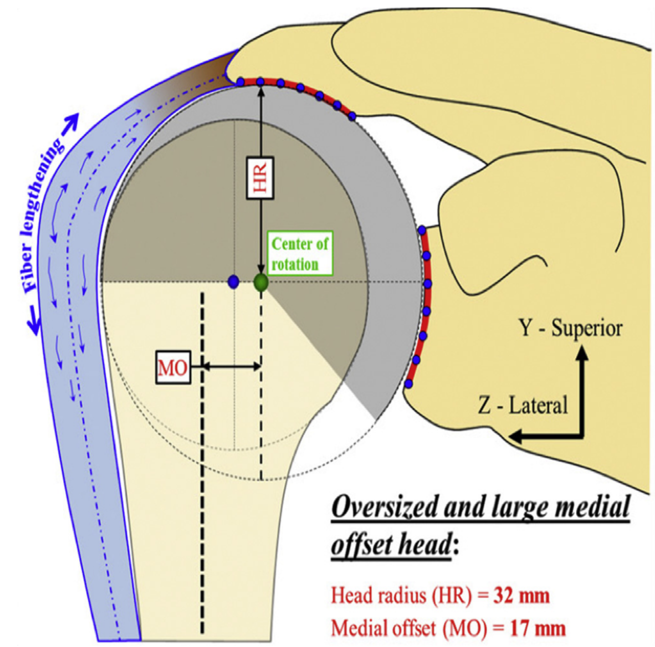

Figure 1 Illustration of cuff tear arthropathy hemiarthroplasty with oversized head and large medial offset *(MO)*. *HR*, head radius.
(Reprinted from *Journal of Biomechanics*, 46, Lemieux PO, Tétreault P, Hagemeister N, Nuño N, Influence of prosthetic humeral head size and medial offset on the mechanics of the shoulder with cuff tear arthropathy: A numerical study, 806-812, February 2013, with permission from Elsevier.)

chronic effusion, which should be evaluated intraoperatively. Pressing the elbow to the patient's side and observing it spring away when the pressure is released is one way the surgeon can judge the tensioning of the deltoid.[37] Humeral retroversion is patient specific but is often increased to nearly 20°-30° to maximize prosthesis stability. Impaction grafting is used, when possible, during fixation of the humeral stem to optimize bone stock. When impaction grafting is not possible, cement may be used for humeral stem fixation. Prior to final cementation, particular attention should be paid to the height of the stem to appropriately restore deltoid tension. Furthermore, resection of excess tuberosity extending beyond the curvature of the extended head is necessary to reduce impingement during abduction and external rotation. Subscapularis repair is performed with nonabsorbable transosseous sutures, and stability is augmented by the inferior sheet of the clavipectoral fascia, in addition to preserving the CA ligament.[29] A summary of tips and tricks for use during implantation of the CTA hemiarthroplasty can be found in Table II.

Modern primary indications

Ideal candidates for modern use of the CTA hemiarthroplasty include low-demand, elderly patients with significant comorbidities, a primary complaint of pain, and modest functional expectations. Ideal candidates have an intact CA arch and preserved forward elevation, as these structures are critical to prosthesis function and stability. The overwhelming majority of patients with advanced CTA today will be candidates for RSA. However, there are certain scenarios in which a CTA prosthesis can be considered for severe arthropathy in the primary setting, especially in patients aged > 70 years who desire to avoid the complications and risk of revision surgery associated with RSA. Instability accounts for up to 30% of all complications after RSA and is the most common cause of early revision.[9,13,29] In their initial cohort of 60 patients, Visotsky et al[41] reported no dislocations following CTA hemiarthroplasty at a mean follow-up of 32 months. Other complications unique to RSA and not seen in hemiarthroplasty include scapular notching, acromial and scapular spine fractures, baseplate loosening, modular humeral component dissociation, dissociation of the glenosphere from the baseplate, polyethylene wear, and neurologic complications associated with overlengthening.[29] Elderly patients may not tolerate repeated hospitalizations, immobilization, and prolonged rehabilitation associated with reoperation and revision. Treatment with a CTA prosthesis may provide satisfactory improvements in pain and function while mitigating the risk of complications.

Furthermore, special cases for the use of a CTA hemiarthroplasty may include acromial fragmentation, axillary nerve palsy, and severe glenoid bone loss with a poor prognosis for successful baseplate fixation. Abdelfattah et al[1] found that the risk of complications with RSA was highest in patients with deltoid dysfunction or an acromial fracture. Boileau[10] similarly noted that 2 of the greatest risk factors for instability following RSA are glenoid bone loss and deltoid atrophy. In elderly patients with significant glenoid defects or bone loss, reconstruction with RSA and glenoid augmentations may be costly and technically demanding. CTA hemiarthroplasty may provide a simpler alternative, with a shorter operative time, decreased blood loss, satisfactory function, and resolution of pain. Patients should be counseled preoperatively regarding the modest functional expectations after CTA hemiarthroplasty as those desiring a higher level of function may not be ideal candidates.

Rarely, young patients present with CTA and preserved subscapularis, teres minor, and glenohumeral kinematics. These patients are not candidates for tendon transfers because of the presence of arthrosis, and they are poor candidates for RSA because of their activity level and life expectancy. CTA hemiarthroplasty may provide pain relief, as well as moderate functional outcomes, and allow for eventual delayed conversion to RSA in the young patient with cuff arthropathy.

Table II
Tips and tricks for use during implantation of CTA hemiarthroplasty

During exposure, care should be taken to preserve the anterior soft tissues, clavipectoral fascia, subscapularis, and CA ligament.
Neck resection is performed along the lower anatomic neck.
The native radius of curvature should be measured and matched to the corresponding prosthesis.
Deltoid tension can be evaluated by pressing the elbow to the patient's side and observing the "spring" when pressure is released.
Humeral retroversion is often increased to 20°-30° to maximize prosthesis stability.
Impaction grafting is used, when possible, during fixation of the humeral stem to optimize bone stock.
Cemented fixation may be necessary in the revision setting or when impaction grafting is not possible.
When cement is used, particular attention should be paid to the height of the stem and corresponding deltoid tension.
Resection of excess tuberosity extending beyond the curvature of the prosthesis is necessary to reduce impingement.
Subscapularis repair is augmented by the inferior sheet of clavipectoral fascia, in addition to preserving the CA ligament.
In the revision setting, well-positioned stems may be converted to a CTA prosthesis if allowed by system modularity.

CTA, cuff tear arthropathy; *CA*, coracoacromial.

Revision indications

CTA hemiarthroplasty is also a useful tool in the revision and salvage setting. With RSA utilization increasingly rapidly, the subsequent number of revisions is also expected to dramatically increase.[17,23,36,43] Despite increased familiarity and improvements in surgical technique over the past several years, the complication rate of RSA ranges from 15% to 59% and the revision rate is >10%.[1,6,22,43] Wagner et al[42] demonstrated successful results with the use of revision RSA as a salvage procedure for failed primary RSA. They observed pain relief, improvements in functional outcome scores, and improved range of motion in a series of 27 patients at a mean of 4.4 years' follow-up. They reported a 5-year surgery-free interval in 85% of patients and an overall complication rate of 22%. Other authors have described a complication rate > 30% after revision RSA.[11,13] Despite technological advancements in revision prostheses and custom augmentations, there are scenarios in which the degree of glenoid bone loss may be too extreme to permit reimplantation. Boileau et al[11] reported that retention of a reverse prosthesis at the time of revision was not possible 14% of the time. The use of the extended humeral head hemiarthroplasty may be an option in this situation. Conversion to CTA hemiarthroplasty can be performed with modular conversion from a reverse prosthesis to the extended humeral head with retention of the humeral stem. Avoiding stem exchange is advantageous in limiting blood loss, bone loss, the operative time, fractures, and the infection rate. In situations in which modular conversion cannot be performed, implantation may be supplemented by impaction grafting to account for bone loss.[29] CTA hemiarthroplasty may also provide a lower likelihood of reoperation and additional surgical intervention within the short- to mid-term follow-up period.[23] This may be particularly beneficial in elderly patients with significant comorbidities who wish to avoid prolonged rehabilitation and a complicated recovery.

CTA hemiarthroplasty may also be used in the young patient with a failed RSA. Indications for reverse prostheses are expanding to younger patients; however, the failure rates in this population have been reported to be as high as 15%.[15] If there are significant glenoid bone deficits following failed RSA, younger patients can undergo staged treatment with a CTA hemiarthroplasty. In the first stage, glenoid defects undergo bone grafting and the RSA stem is retained but converted to a CTA hemiarthroplasty. After graft healing, the stem may be converted back to a definitive reverse prosthesis.

Another salvage indication for CTA prosthesis is after RSA failure due to infection. Infection rates after RSA are nearly 6 times higher than those after TSA.[9,43] The extended humeral head of the prosthesis occupies dead space and may provide satisfactory function when used as a dynamic spacer. Following resolution of a periprosthetic joint infection, there may be significant glenoid bone loss at the time of reimplantation. CTA hemiarthroplasty may be used definitively in this scenario. Mahure et al[27] reported that in the elderly patient with multiple comorbidities and an infected shoulder arthroplasty, definitive use of an antibiotic-laden cemented hemiarthroplasty may effectively eradicate infection while providing satisfactory functional results.

Outcomes

Since the original description of the CTA hemiarthroplasty in 2004, few studies have been published on the outcomes. Visotsky et al[41] were the first group to perform CTA hemiarthroplasty; they treated a cohort of 60 patients with an average age of 70.4 years and a mean follow-up period of 32.4 months. The average improvement in forward flexion was more than doubled to 116°, and the average external rotation tripled to 30°. Visual analog scale (VAS) scores for pain decreased from 9.3 preoperatively to 1.9, and an overall success rate of 89% was found. The authors reported no cases of acromial fracture, dislocation, or substantial glenoid changes. Basamania and Bal[8] performed CTA hemiarthroplasty in 132 patients, of whom 88% reported their outcomes as excellent or good, with significant improvements in forward elevation, external rotation, and pain and functional scores. They reported no cases of loosening, infection, or progressive acromial wear.

Arnold et al[3] reported maintained active humeral elevation and satisfactory functional outcome measures in 21 of 24 patients with CTA hemiarthroplasty at a mean age of 75 years. No cases of glenoid erosion, prosthesis migration, or instability were seen during the average follow-up period of 30 months. Firestone et al[19] performed a case series of 22 patients who underwent primary CTA hemiarthroplasty with a mean follow-up period of 43 months, and they reported improvements in pain and function. However, 18% of the cohort was either dissatisfied with treatment or underwent conversion to RSA. Filho et al[18] described pain resolution in all 23 patients who received CTA hemiarthroplasty in their study. Improvements in functional scores and range of motion were also observed, with a 95% patient satisfaction rate at an average follow-up of 20 months. Somerson et al[38] evaluated a mixed cohort of traditional and CTA hemiarthroplasty prostheses and reported that patients with an intact teres minor, intact subscapularis, and lower preoperative external rotation had a better prognosis for achieving clinical improvement after hemiarthroplasty.

Matsen et al[29] in 2019 published a series of 50 patients receiving CTA hemiarthroplasty with a mean age of 71 years and a minimum 2-year follow-up and found significant improvements in functional outcomes. The percentage of patients able to sleep comfortably increased from 19% to 71% ($P < .01$); the percentage able to place a coin on a shelf at shoulder level increased from 38% to 86% ($P < .01$); and the percentage able to wash the back of the opposite shoulder increased from 17% to 62% ($P < .01$). The authors reported no complications, revisions, or failures within 2 years of follow-up. However, their strict inclusion criteria and patient selection may limit the ability to extrapolate these results to other patient populations. The patients in this study had retained active elevation > 90°; typically were aged ≥ 70 years; had low preoperative patient-reported outcome scores and high presurgical optimism; and typically had Seebauer type I arthropathy and Walch type A glenoids without glenoid retroversion.[29]

CTA hemiarthroplasty has not been extensively analyzed in the revision or salvage setting. Hemiarthroplasty is traditionally contraindicated in cases of advanced arthropathy because of concerns regarding superior prosthesis escape. This may raise concern regarding the use of the CTA prosthesis in the revision or salvage setting. There are several small case series describing conversion to traditional hemiarthroplasty after failed RSA or infection. Glanzmann et al[23] reported a series of 16 patients with failed RSA and insufficient glenoid bone stock to support reimplantation of a reverse prosthesis. Conversion to hemiarthroplasty showed variable results, with half of the patients experiencing significant pain relief and satisfactory function and the other half reporting dissatisfaction. Of note, only 1 patient in this cohort received a CTA hemiarthroplasty. Mahure et al[27] published a series of patients who underwent revision to an antibiotic-laden cemented hemiarthroplasty following an infected shoulder arthroplasty. Of the 9 patients available for final follow-up at a mean of 4 years, 89% were reported to have good or fair American Shoulder and Elbow Surgeons scores, with no patients showing clinical or radiologic evidence of recurrent infection. Ince et al[24] reported a retrospective series of patients with infected shoulder arthroplasty and 1-stage conversion to antibiotic-cemented hemiarthroplasty at a mean follow-up of 5.8 years. Of the 9 patients available for final follow-

Figure 2 Anteroposterior radiograph of left shoulder showing severe rotator cuff arthropathy with superior humeral migration, glenoid bone loss, and incompetent coracoacromial arch in case 1.

up, 5 reported the ability to perform activities of daily living, 2 reported the ability to perform light activities, and 2 reported the ability to perform light activities within the home. There were no cases of recurrent infection, and 6 of 9 patients reported satisfaction with the procedure. The 3 patients who were unsatisfied experienced superior escape of the hemiarthroplasty. When comparing the primary use of CTA designs in patients with severe arthropathy (Seebauer type IIB disease), Carvalho et al[12] reported statistically significant improvements in pain, range of motion, and functional scores with no difference between Seebauer classification groups.

The senior author has had success using the CTA hemiarthroplasty in the primary, revision, and salvage settings for all Seebauer types and believes this prosthesis is a useful tool in select cases of severe bone deficiency despite the risks of superior prosthesis escape. The following cases illustrate the clinical utilization of the CTA prosthesis. All patients provided informed consent for inclusion in this review.

Case 1

An 83-year-old female patient with bilateral rotator CTA presented to the clinic with severe left shoulder pain and pseudoparalysis. She had previously undergone successful right-sided RSA performed by the senior author 1 year earlier, with an excellent outcome. Radiographs of the left shoulder showed Seebauer type IIB disease with superior migration of the humeral head, fragmentation of the acromion, and severe bone loss in the superior glenoid (Fig. 2). Computed tomography examination was performed and showed severe medialization of the glenoid and articular step-off. The remaining glenoid was severely deficient. The patient reported a primary complaint of pain and the desire to return to low-demand activities, primarily within the home. After a thorough discussion of the risks and benefits of each procedure, the patient provided consent for RSA vs. CTA hemiarthroplasty pending intraoperative evaluation. Intraoperatively, the acromion was

Figure 3 Anteroposterior radiograph showing extended humeral head (cuff tear arthropathy) hemiarthroplasty in appropriate alignment at approximately 12 months' follow-up in case 1. There is no radiographic evidence of progressive acromial or glenoid wear.

observed to be severely fragmented and eroded medially to the clavicle. The deltoid origin was severely compromised. The glenoid was visualized, and there was severe medialization of the superior glenoid with articular step-off. The remaining glenoid was deficient and was deemed insufficient to support baseplate fixation. The decision was made to proceed with CTA hemiarthroplasty. A reamer was used to minimally contour both the glenoid and subacromial surfaces and to reduce the articular step-off. A CTA hemiarthroplasty was implanted with special attention paid to the curvature and resection of the humeral head, deltoid tension, and tuberosity impingement as previously described (Figs. 3 and 4). The subscapularis tendon was repaired to help provide anterior stability, along with the clavipectoral fascia.

Postoperatively, the extremity was maintained in a shoulder orthosis with restricted weight bearing. At 2 weeks, the patient began passive range-of-motion exercises, followed by active motion at 6 weeks and strengthening and resistance exercises at 12 weeks. At 2 years' follow-up, she was pain free with 90° of forward flexion, 60° of external rotation, and 45° of internal rotation. No complications, reoperations, or revision surgery occurred, and she reported excellent satisfaction.

Case 2

A 62-year-old male patient with rotator CTA returned to the clinic with significant shoulder pain and instability 15 months after a left-sided RSA. Radiographs showed loosening and failure of the glenoid baseplate with screw cutout superiorly (Fig. 5). Preoperative dual-energy x-ray absorptiometry scan showed severe osteoporosis with bone mineral density 3.5 standard deviations below normal. The patient primarily complained of pain and the desire to return to low-demand activities of daily living. After a thorough discussion, he provided consent and was scheduled for surgery consisting of revision RSA vs. CTA hemiarthroplasty. In the operating room, the glenoid was inspected and showed a significant defect superiorly at the site of screw cutout. The screw holes and areas with bone loss were filled with calcium phosphate. Owing to the degree of glenoid bone loss, severely deficient bone mineral density, patient comorbidities, and low functional status of the

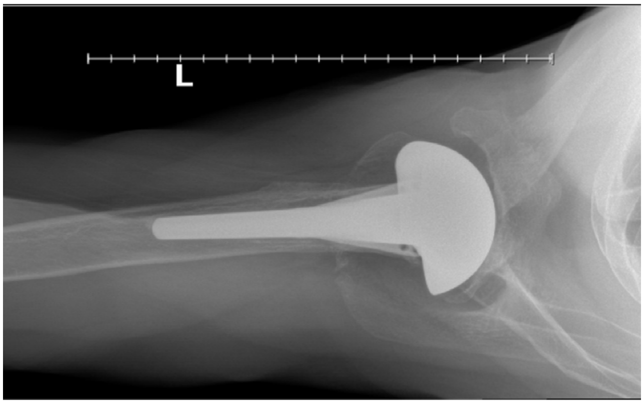

Figure 4 Axillary radiograph showing extended humeral head (cuff tear arthropathy) hemiarthroplasty in appropriate alignment at approximately 12 months' follow-up in case 1. There is no radiographic evidence of progressive acromial or glenoid wear.

patient, the decision was made to convert the prosthesis to a CTA hemiarthroplasty.

The patient followed the standard rehabilitation protocol. At most recent follow-up, 18 months from the date of surgery, he was able to perform all activities of daily living and rated his pain as 2 of 10 on a VAS. He was able to achieve forward flexion to 80°, external rotation to 60°, and internal rotation to 40°. He was overall very satisfied with the procedure and had not experienced any complications or reoperations.

Case 3

An 86-year-old male patient presented with debilitating right shoulder pain, as well as chronic pseudoparalysis with <40° of active forward flexion. Radiographs showed severe arthropathy with superior humeral escape and severe glenoid bone loss (Seebauer type IIB). A computed tomography scan was obtained to evaluate the degree of bone loss and showed marked glenoid

Figure 5 Anteroposterior radiograph showing failed reverse shoulder arthroplasty with glenoid component screw cutout in case 2.

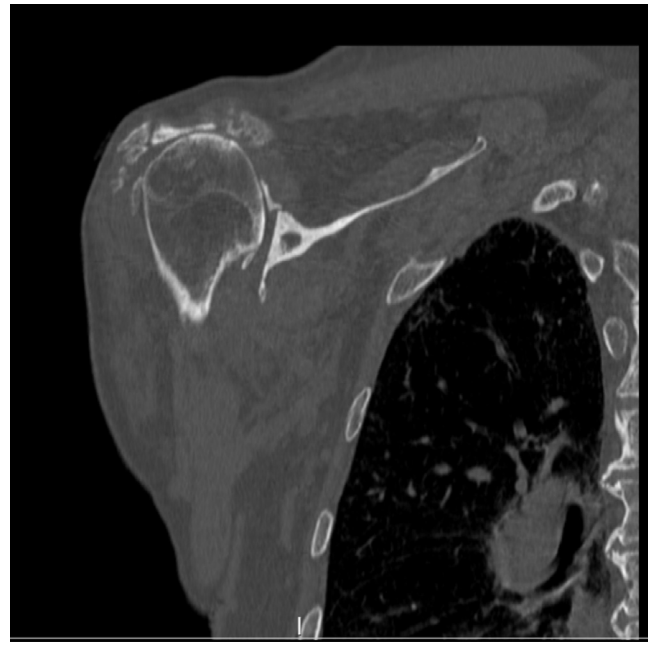

Figure 6 Coronal computed tomography image showing superior humeral escape, acromial fragmentation, and severe glenoid bone loss in case 3.

medialization beyond the coracoid, as well as thinning and fragmentation of the acromion (Fig. 6). The patient primarily complained of pain and the desire to return to household activities, and he was counseled regarding RSA vs. CTA hemiarthroplasty. In the operating room, the acromion was inspected and again noted to be very thin and fragmented. Exposure of the glenoid showed substantial bone loss and medialization. Owing to the combination of these risk factors, along with the patient's medical comorbidities, advanced age, and low functional status, the decision was made to proceed with CTA hemiarthroplasty.

The patient progressed through the rehabilitation protocol as described previously. At 1 year of follow-up, he demonstrated 85° of forward flexion, 55° of external rotation, and 40° of internal rotation. He reported a VAS score of 1 of 10, was able to perform all household activities, and had experienced no complications, reoperations, or revision surgery.

Conclusion

Despite the increased utilization of the RSA, there is a surgical option for the use of the CTA hemiarthroplasty in select clinical presentations. This prosthesis may provide patients with improved comfort and function while avoiding many of the complications associated with RSA. Ideally indicated in low-demand, elderly patients with CTA and a primary complaint of pain, the CTA design reliably reduces pain while providing modest function within the daily activities of this population.[3,8,12,18,19,29,41] In addition, the benefits of a shorter operative time, lower blood loss, and low complication and reoperation rates make the CTA prosthesis a reasonable treatment option in this population. Patients should be counseled extensively regarding postoperative functional expectations, as active patients, as well as patients desiring a higher level of function, may not be satisfied postoperatively. In addition, progressive subacromial and glenoid erosion may occur with long-term use of the CTA design, potentially diminishing shoulder function. As the utilization of RSA continues to increase in popularity, CTA hemiarthroplasty may also become a useful tool in the revision or salvage setting. The ultimate treatment strategy following failed RSA remains complex, with each case requiring individual evaluation and treatment planning. There is sparse literature regarding the use of the CTA prosthesis in this setting, and high-quality, prospective, comparative studies will be helpful for future guidance.

Disclaimer

The 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. Abdelfattah A, Otto RJ, Simon P, Christmas KN, Tanner G, LaMartina J, et al. Classification of instability after reverse shoulder arthroplasty guides surgical management and outcomes. J Shoulder Elbow Surg 2018;27:e107–18. https://doi.org/10.1016/j.jse.2017.09.031.
2. Adams R. Illustrations of the effects of rheumatic gout or chronic rheumatic arthritis on all the articulations with descriptive and explanatory statements. 1857. Clin Orthop Relat Res 1999;366:4–7.
3. Arnold RM, Sun J, Weber JP, Fehringer EV. Evaluation of a cuff tear arthropathy hemiprosthesis for the treatment of glenohumeral arthritis in the presence of a chronic rotator cuff tear. Shoulder Elbow 2010;2:13–6. https://doi.org/10.1111/j.1758-5740.2009.00035.x.
4. Arntz CT, Jackins S, Matsen FA III. Prosthetic replacement of the shoulder for the treatment of defects in the rotator cuff and the surface of the glenohumeral joint. J Bone Joint Surg Am 1993;75:485–91.
5. Arntz CT, Matsen FA III, Jackins S. Surgical management of complex irreparable rotator cuff deficiency. J Arthroplasty 1991;6:363–70.
6. Bacle G, Nové-Josserand L, Garaud P, Walch G. Long-term outcomes of reverse total shoulder arthroplasty: a follow-up of a previous study. J Bone Joint Surg Am 2017;99:454–61. https://doi.org/10.2106/JBJS.16.00223.
7. Basamania CJ. Arthroplasty for cuff tear arthropathy: when half a loaf will do. Semin Arthroplasty 2004;15:198–201. https://doi.org/10.1053/j.sart.2004.12.023.
8. Basamania CJ, Bal GK. Cuff tear arthropathy treated with a DePuy CTA prosthesis: midterm results. J Shoulder Elbow Surg 2007;16:e24. https://doi.org/10.1016/j.jse.2007.02.008.
9. Bohsali KI, Bois AJ, Wirth MA. Complications of shoulder arthroplasty. J Bone Joint Surg Am 2017;99:256–69. https://doi.org/10.2106/JBJS.16.00935.
10. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res 2016;102:S33–43. https://doi.org/10.1016/j.otsr.2015.06.031.
11. Boileau P, Melis B, Duperron D, Moineau G, Rumian AP, Han Y. Revision surgery of reverse shoulder arthroplasty. J Shoulder Elbow Surg 2013;22:1359–70. https://doi.org/10.1016/j.jse.2013.02.004.
12. Carvalho CD, Andreoli CV, de Castro Pochini A, Ejnisman B. Use of cuff tear arthroplasty head prosthesis for rotator cuff arthropathy treatment in elderly patients with comorbidities. Einstein (Sao Paulo) 2016;14:520–7. https://doi.org/10.1590/s1679-45082016ao3372.
13. Chalmers PN, Boileau P, Romeo AA, Tashjian RZ. Revision reverse shoulder arthroplasty. J Am Acad Orthop Surg 2019;27:426–36. https://doi.org/10.5435/JAAOS-D-17-00535.
14. Ecklund KJ, Lee TQ, Tibone J, Gupta R. Rotator cuff tear arthropathy. J Am Acad Orthop Surg 2007;15:340–9. https://doi.org/10.5435/00124635-200706000-00003.
15. Ek ETH, 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.
16. Ernstbrunner L, Suter A, Catanzaro S, Rahm S, Gerber C. Reverse total shoulder arthroplasty for massive, irreparable rotator cuff tears before the age of 60 years: long-term results. J Bone Joint Surg Am 2017;99:1721–9. https://doi.org/10.2106/JBJS.17.00095.
17. Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D. Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? Clin Orthop Relat Res 2011;469:2469–75. https://doi.org/10.1007/s11999-011-1833-y.
18. Filho RB, Ribeiro FR, Tenor AC, Filho CSF, da Costa GBL, Storti TM, et al. Results of surgical treatment of denerative arthropathy of the rotator cuff using hemiarthroplasty—CTA. Rev Bras Ortop 2015;47:66–72. https://doi.org/10.1016/S2255-4971(15)30347-5.
19. Firestone D, Arnold RM, Fehringer EV. Two-year follow-up of shoulder hemiarthroplasty with a CTA head for cuff-tear arthropathy. Shoulder Elbow 2012;4:174–8. https://doi.org/10.1111/j.1758-5740.2012.00187.x.
20. Flatow EL, Harrison AK. A history of reverse total shoulder arthroplasty. Clin Orthop Relat Res 2011;469:2432–9. https://doi.org/10.1007/s11999-010-1733-6.
21. Franklin JL, Barrett WP, Jackins SE, Matsen FA III. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty 1988;3:39–46.
22. Gerber C, Canonica S, Catanzaro S, Ernstbrunner L. Longitudinal observational study of reverse total shoulder arthroplasty for irreparable rotator cuff dysfunction: results after 15 years. J Shoulder Elbow Surg 2018;27:831–8. https://doi.org/10.1016/j.jse.2017.10.037.
23. Glanzmann MC, Kolling C, Schwyzer H-K, Audigé L. Conversion to hemiarthroplasty as a salvage procedure for failed reverse shoulder arthroplasty. J Shoulder Elbow Surg 2016;25:1795–802. https://doi.org/10.1016/j.jse.2016.03.011.
24. Ince A, Seemann K, Frommelt L, Katzer A, Loehr JF. One-stage exchange shoulder arthroplasty for peri-prosthetic infection. J Bone Joint Surg Br 2005;87-B:814–8. https://doi.org/10.1302/0301-620X.87B6.15920.
25. Krishnan SG, Bennion PW, Reineck JR, Burkhead WZ. Hemiarthroplasty for proximal humeral fracture: restoration of the Gothic arch. Orthop Clin North Am 2008;39:441–50. https://doi.org/10.1016/j.ocl.2008.05.004.
26. Lemieux PO, Tétreault P, Hagemeister N, Nuño N. Influence of prosthetic humeral head size and medial offset on the mechanics of the shoulder with cuff tear arthropathy: a numerical study. J Biomech 2013;46:806–12. https://doi.org/10.1016/j.jbiomech.2012.11.021.
27. Mahure SA, Mollon B, Yu S, Kwon YW, Zuckerman JD. Definitive treatment of infected shoulder arthroplasty with a cement spacer. Orthopedics 2016;39:e924–30. https://doi.org/10.3928/01477447-20160623-07.
28. Marmor L. Hemiarthroplasty for the rheumatoid shoulder joint. Clin Orthop Relat Res 1977;122:201–3.
29. Matsen FA III, Somerson JS, Hsu JE, Lippitt SB, Russ SM, Neradilek MB. Clinical effectiveness and safety of the extended humeral head arthroplasty for selected patients with rotator cuff tear arthropathy. J Shoulder Elbow Surg 2019;28:483–95. https://doi.org/10.1016/j.jse.2018.08.020.
30. Muh SJ, Streit JJ, Wanner JP, Lenarz CJ, Shishani Y, Rowland DY, et al. Early follow-up of reverse total shoulder arthroplasty in patients sixty years of age or younger. J Bone Joint Surg Am 2013;95:1877–83. https://doi.org/10.2106/JBJS.L.10005.
31. Neer CS II. Replacement arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 1974;56:1–13.
32. Neer CS II. Articular replacement for the humeral head. J Bone Joint Surg Am 1955;37-A:215–28.
33. Neer CS II, Craig EV, Fukuda H. Cuff-tear arthropathy. J Bone Joint Surg Am 1983;65:1232–44.
34. Neer CS II, Watson KC, Stanton FJ. Recent experience in total shoulder replacement. J Bone Joint Surg Am 1982;64:319–37.
35. Nolan BM, Ankerson E, Wiater JM. Reverse total shoulder arthroplasty improves function in cuff tear arthropathy. Clin Orthop Relat Res 2011;469:2476–82. https://doi.org/10.1007/s11999-010-1683-z.
36. Palsis JA, Simpson KN, Matthews JH, Traven S, Eichinger JK, Friedman RJ. Current trends in the use of shoulder arthroplasty in the United States. Orthopedics 2018;41:e416–23. https://doi.org/10.3928/01477447-20180409-05.
37. Rockwood Jr CA, Matsen III FA, Wirth MA, Lippitt SB, Fehringer EV, Sperling JW, editors. Rockwood and Matsen's the shoulder. 5th ed. Elsevier: Amsterdam; 2017.
38. Somerson JS, Sander P, Bohsali K, Tibbetts R, Rockwood CA Jr, Wirth MA. What factors are associated with clinically important improvement after shoulder hemiarthroplasty for cuff tear arthropathy? Clin Orthop Relat Res 2016;474:2682–8. https://doi.org/10.1007/s11999-016-5037-3.
39. Thompson WO, Debski RE, Boardman ND, Taskiran E, Warner JJP, Fu FH, et al. A biomechanical analysis of rotator cuff deficiency in a cadaveric model. Am J Sports Med 1996;24:286–92.
40. Torrens C, Corrales M, Melendo E, Solano A, Rodríguez-Baeza A, Cáceres E. The pectoralis major tendon as a reference for restoring humeral length and retroversion with hemiarthroplasty for fracture. J Shoulder Elbow Surg 2008;17:947–50. https://doi.org/10.1016/j.jse.2008.05.041.
41. Visotsky JL, Basamania C, Seebauer L, Rockwood CA, Jensen KL. Cuff tear arthropathy: pathogenesis, classification, and algorithm for treatment. J Bone Joint Surg Am 2004;86-A(Suppl 2):35–40.
42. Wagner ER, Hevesi M, Houdek MT, Cofield RH, Sperling JW, Sanchez-Sotelo J. Can a reverse shoulder arthroplasty be used to revise a failed primary reverse shoulder arthroplasty? Bone Joint J 2018;100-B:1493–8. https://doi.org/10.1302/0301-620X.100B11.BJJ-2018-0226.R2.
43. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 2011;20:146–57. https://doi.org/10.1016/j.jse.2010.08.001.