Challenges in Reverse Shoulder Arthroplasty: Addressing Glenoid Bone Loss

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Abstract

Reverse shoulder arthroplasty (RSA) was designed for the treatment of elderly patients with cuff tear arthropathy. Because of its success, the indications for RSA have expanded beyond cuff tear arthropathy to include acute fractures, fracture sequelae, massive rotator cuff tears, inflammatory arthritis, and revision shoulder arthroplasty. Consequently, the number of RSAs performed has increased steadily. Glenoid bone loss is not uncommon in patients undergoing primary or revision RSA. Failure to appreciate and address glenoid bone loss during RSA can lead to improper baseplate positioning and early failure or complications such as dislocation or scapular notching. The authors present a review of the current literature as well as recommended strategies for characterization of glenoid bone loss and preferred surgical techniques for addressing bone loss during RSA. [Orthopedics. 2016; 39(1):14-23.]
Intraoperative glenoid erosion is frequent in CTA with a reported incidence of nearly 40%. In contrast to osteoarthritis, where glenoid bone loss primarily occurs in the horizontal plane, patients with CTA often present with bone loss in the vertical plane. On the basis of diagnosis alone, patients with CTA are not candidates for anatomic shoulder arthroplasty and are best treated with RSA. For these patients, an emphasis should be placed on the identification and management of abnormal glenoid morphology. Failure to appreciate and address significant change in glenoid inclination and wear in the vertical plane can lead to improper placement of the baseplate. The most common error in this situation is failure to address superior erosion, leading to placement of a baseplate with superior tilt, which increases the risk of complications, including early baseplate failure.

**Clinical Scenarios**

Glenoid bone loss is often multidirectional and requires correction in more than 1 plane. However, for the purposes of discussion and planning, it is helpful to describe deformities in the predominant plane. There are 4 typical scenarios in which glenoid bone loss is encountered and needs to be addressed when planning for and performing RSA: primary osteoarthrosis with horizontal glenoid bone deficiency–posterior glenoid erosion or retroversion (Walch B2/C), inflammatory arthritis with central glenoid erosion and joint line medialization (Walch A2, Lévrier stage 2/3), CTA with vertical bone deficiency (Favard E2/E3/E4), and revision arthroplasty with glenoid bone defects.

**Primary Osteoarthritis**

The incidence of abnormal glenoid morphology and/or humeral head subluxation in glenohumeral osteoarthritis is greater than 50%. The morphologic changes in osteoarthritis are predominantly in the horizontal plane, most commonly posterior humeral head subluxation with or without posterior glenoid bone loss. In the majority of cases, these changes are mild and can be addressed with anatomic shoulder arthroplasty and well-described techniques such as eccentric reaming and/or an augmented glenoid component. In cases with more severe humeral head subluxation (>80%) or significant posterior glenoid erosion, poor functional results and high complication rates have been reported when patients are treated with anatomic arthroplasty. The poor functional results, high rates of recurrent instability, and early glenoid loosening have led to the use of RSA in this setting. Reverse shoulder arthroplasty allows the surgeon to address the static posterior instability and glenoid erosion.

**Cuff Tear Arthropathy**

Cuff tear arthropathy is the most common indication for RSA. Abnormal glenoid morphology and bone loss is frequently seen in CTA, with a reported incidence of nearly 40%. In contrast to osteoarthritis, where glenoid bone loss primarily occurs in the horizontal plane, patients with CTA often present with bone loss in the vertical plane. On the basis of diagnosis alone, patients with CTA are not candidates for anatomic shoulder arthroplasty and are best treated with RSA. For these patients, an emphasis should be placed on the identification and management of abnormal glenoid morphology. Failure to appreciate and address significant change in glenoid inclination and wear in the vertical plane can lead to improper placement of the baseplate. The most common error in this situation is failure to address superior erosion, leading to placement of a baseplate with superior tilt, which increases the risk of complications, including early baseplate failure.

**Revision Arthroplasty**

Reverse shoulder arthroplasty has become a successful treatment option for patients in salvage situations, including the revision setting. Glenoid bone loss is commonly encountered during revision shoulder arthroplasty. Significant bone loss, if not addressed, may compromise baseplate fixation and lead to glenoid component loosening. Unlike the aforementioned scenarios (osteoarthritis, inflammatory arthritis, CTA), there is not a characteristic pattern of glenoid bone loss for revision shoulder arthroplasty. The bone loss is variable and largely dependent on the previous implant present, the mode of failure, and the process used to remove the implant. Although the causes and workup of failed shoulder arthroplasty are beyond the scope of this article, options and techniques for addressing glenoid defects at the time of revision to RSA are discussed.

**Classification**

Glenoid morphology and bone loss can be described using several well-established classification systems. Horizontal plane glenoid morphology is best described using the Walch classification (Figure 1), Vertical plane glenoid morphology can be described using the Favard classification (Figure 2). Central wear and glenoid medialization in patients with rheumatoid arthritis can be characterized based on the classification by Lévrier and Franceschi (Figure 3). In the revision setting, classification of bone loss is more difficult. Antuna et al described intraoperative glenoid wear at the time of revision based on location and extent of erosion. Williams and Iannotti later modified this classification for use in both primary and revision settings (Figure 4).
Preoperative planning is crucial for proper characterization of glenoid bone loss and to determine the need for bone graft. Furthermore, precise measurement of version, inclination, and depth of defects can aid in bone graft selection and preparation. Imaging should be used to plan guide pin, central peg or screw, and peripheral screw placement based on remaining bone stock.

Imaging
Plain radiographs are essential and include true anteroposterior view (Grashey view), axillary view, and scapular Y view. In the setting of revision arthroplasty to RSA, it is also helpful to have full-length scaled radiographs of both humeri to properly assess humeral shortening and excessive medialization.

Advanced imaging is necessary in most cases of glenoid bone loss for adequate preoperative planning, with computed tomography (CT) being the modality of choice due to its accuracy in assessing glenoid morphology. It is imperative that CT images be in the scapular plane and perpendicular to the scapular plane for accurate characterization of the glenoid. Three-dimensional (3D) CT images provide a global view of the bone loss and are routinely used in the authors’ practice.

Measurement of Version, Inclination, and Bone Loss
Several methods have been described to measure glenoid version (horizontal plane), inclination (vertical plane), and bone loss. Computed tomography allows for accurate measurements of these parameters. The authors’ preferred method of measuring glenoid version has been described previously and involves the use of Friedman’s line and the intermediate glenoid line as described by Rouleau et al.

Recently, the authors have proposed a modification to this measurement termed the “reverse shoulder angle” to avoid underestimation of glenoid inclination at the

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**Figure 1:** Walch classification of glenoid erosion in primary glenohumeral arthritis. (Reprinted from *Journal of Arthroplasty, 14, Walch G, Badet R, Boulahia A, Khoury A, Morphologic study of the glenoid in primary glenohumeral osteoarthritis, 756-760, 1999, with permission from Elsevier.*)

**Figure 2:** Favard classification of glenoid erosion in cuff tear arthropathy. (Reprinted from *Journal of Shoulder and Elbow Surgery, 17, Lévigne C, Boileau P, Favard L, Garaud P, Molé D, Sirveaux F, Walch G, Scapular notching in reverse shoulder arthroplasty, 925-935, 2008, with permission from Elsevier.*)

**Figure 3:** Lévigne classification of glenoid wear in rheumatoid arthritis on true anteroposterior view: stage 1, subchondral bone intact or minimally deformed (A); stage 2, wear reaching the foot of the coracoid (B); and stage 3, wear beyond the foot of the coracoid (C). (With kind permission from Springer Science+Business Media: *Rheumatoid Arthritis of the Shoulder: Radiological Presentation and Results of Arthroplasty, 1999, 221-230, Lévigne C and Franceschi J, Figure 1.*)
baseplate–glenoid interface. While the $\beta$-angle provides the global glenoid inclination, the reverse shoulder angle provides the inferior glenoid inclination (Figure 6B). Given that an appropriately placed baseplate occupies only the inferior two-thirds of the glenoid, use of the global glenoid inclination can underestimate the focal inclination at the level of the baseplate and lead to placement of a baseplate with superior tilt.

**Three-dimensional Imaging Software and Patient-Specific Instrumentation**

The use of 3D preoperative planning software and patient-specific instrumentation for shoulder arthroplasty has been validated in both cadaveric and clinical studies. Recently, 3D preoperative planning software and patient-specific instruments have become commercially available for guidance in the insertion of the glenoid component in both anatomic arthroplasty and RSA. The process involves uploading standard preoperative CT images of the patient’s scapula, which are used to create a 3D model of the patient’s glenoid (Figures 7A-B). The software allows for accurate assessment of glenoid morphology and assists in precisely measuring version, inclination, bone loss, and dimensions of bone graft. Manufacturer-specific algorithms applied to the 3D model allow templating of guidewire (and central screw/peg) placement and determination of correct baseplate position (Figure 7C). For patient-specific instrumentation, surgeon approval of the 3D preoperative plan leads to the production of a bone model of the patient’s glenoid and a corresponding custom drill guide to determine the insertion point and orientation of the central guidewire (Figure 7D).

**Surgical Technique**

Two surgical approaches are most commonly used for RSA, anterosuperior (AS) and deltopectoral (DP). There is conflicting literature regarding the effect of surgical approach on baseplate position, rate of scapular notching, and loosening. There have been reports of increased rates of superior baseplate tilt, scapular notching, and baseplate loosening when the AS approach is compared with the DP approach. In contrast, Gillespie et al found no difference in baseplate position and rate of scapular notching comparing the AS approach with the DP approach; however, they did confirm increased baseplate superior tilt in the AS group. In this series, strict preoperative criteria were used for selecting patients for the AS approach: (1) no prior open shoulder surgery; (2) greater than 25° of passive external rotation; (3) no significant medial humeral osteophytes; and (4) superior migration completely reducible under anesthesia.

In the authors’ experience, patients with significant glenoid bone loss undergoing RSA almost never meet the aforementioned criteria. In addition, the tendency for superior tilting of the baseplate combined with the frequent need for extended central pegs to accommodate the bone graft further challenge the AS approach. These patients, given their bone loss, are already at high risk for improper placement of the baseplate and subsequent failure. In the setting
of glenoid bone loss, the authors use the DP approach exclusively, feeling it allows for better visualization and understanding of the glenoid morphology and provides improved access for placement of bone graft when necessary.

Methods for Addressing Bone Loss

Current options for addressing glenoid bone loss in the setting of RSA include asymmetric reaming and use of a lateralized implant, bone grafting, and use of an augmented baseplate. The results of augmented baseplates have yet to be established; thus, this technique is not discussed. This article focuses on bone grafting techniques.

Asymmetric Reaming and Use of a Lateralized Implant

The decision regarding whether to use bone graft is most often made preoperatively based on evaluation of imaging and the measurements described above. Surgical goals include correction of horizontal, vertical, and central bone deformities. Excessive medialization of the joint line can occur with all types of deformities and should be corrected. Bone grafting can be used to re-establish the original joint line position or even slightly lateralize it. The advantages of a lateralized center of rotation have been well described and include reduced scapular impingement leading to improved rotation and decreased scapular notching, improved tensioning of the remaining cuff muscles, decreased instability, and improved aesthetic contour of the shoulder.49

Boileau et al49,52 have reported on the technique and results of their method to produce a lateralized center of rotation—the bony increased-offset RSA (BIO-RSA). This technique is used at their institution in all cases of RSA; thus, isolated asymmetric reaming is not part of their treatment algorithm.

An alternative method to obtain relative lateralization of the center of rotation and to avoid excessive medialization involves the use an implant with increased offset built in to the glensphere/baseplate construct (metallic lateralization).53 When using this strategy, there are situations with glenoid bone loss that can be addressed with asymmetric reaming alone. In situ...
ations with minor glenoid deficiency, a modified reaming technique has been described to allow for stable baseplate fixation. This involves using a cannulated system with the central screw oriented in the axis of the scapular spine, passed from the center of the glenoid surface to the junction where the scapular spine joins the body of the scapula. Reaming in this orientation is then performed followed by assessment of the baseplate–glenoid contact. In cases with greater than 80% of bony coverage, the baseplate can be implanted without the need for bone graft. In the description of this technique, Klein et al avoided the use of bone graft in 34 of 56 patients with glenoid bone deficiency.

Bone Grafting

Patients undergoing RSA with moderate to severe glenoid bone loss are best treated with bone grafting. The authors’ preference is to perform bone grafting and RSA as a single-stage procedure whenever possible. A 2-stage procedure is rarely indicated, but scenarios exist in which this may be necessary: concern for infection, inability to adequately tension the RSA (risk of instability), and inability to reduce the RSA without excessive tension.

Bone graft source selection varies widely among surgeons and depends on the amount of bone loss present and bone graft available. In the setting of primary RSA, bone graft is most commonly taken from the humeral head, with different techniques described for harvesting and preparation. In revision cases and primary cases with massive uncontained bone loss, humeral head autograft is not available or is insufficient. In these cases, options include iliac crest autograft and various types of allograft. Below, the authors focus on their preferred techniques for harvesting, preparing, and securing bone graft during RSA.

Humeral Head Autograft

In primary RSA with glenoid bone loss, humeral head autograft can be used in the majority of cases with good results. Although there is no established maximum defect that can be corrected with humeral head autograft, the authors use this technique for asymmetric bone loss up to 25 mm and for version correction up to 50°.

The authors’ preferred technique for harvesting the humeral head bone is similar to that previously described, with modifications to provide a larger asymmetric graft. Boileau has termed this technique the angled Bio-RSA. The details of this technique are as follows (Video).

After exposure and dislocation of the humeral head, an oscillating saw is used to remove a small amount of bone—enough to provide a flat surface—at the summit of the humeral head. A threaded guidewire is then placed perpendicular to this cut and driven to the lateral cortex of the humerus (Figure 8A). Next, a cannulated drill is used to bore a central hole, 8 mm in diameter (Figure 8B). A bell saw with the diameter corresponding to the planned baseplate dimensions (generally 25 mm for females and 29 mm for males) is passed to the desired depth (Figure 8C). A small osteotome is then passed through an anterior cortical window to free the bone graft distally at the desired depth. The bone graft is removed (Figure 8D) and inserted over the peg of the baseplate, and a freehand sawcut is performed to modify the angle or thickness of the graft (Figure 8E).

It is critical to consider using a baseplate with a lengthened (25 mm) central peg to allow for adequate penetration into native glenoid bone at time of impaction. In cases of very large defects, where the autograft is larger than 15 mm, it may be necessary to use an even longer central peg (30 or 35 mm). Selection of central peg length is also influenced by glenoid size. For example, in small females, 25 mm may be long enough to obtain adequate purchase in native bone, even with an appropriately sized graft in place. In addition, threaded central pegs are available in some systems and can provide additional compression and stability of fixation. Prior to moving on to the glenoid, the humeral osteotomy is performed.

Excellent glenoid exposure is essential for successful implant and graft placement. Once the glenoid is exposed, a threaded guidewire is inserted into the glenoid vault, a step aided with preoperative image templating (and, in some instances, with patient-specific instrumentation). The guidewire is placed at a level to allow the baseplate to sit flush with the inferior border of the glenoid and at an inferior angle of 10°. A small
Trending in Orthopedics

mm) reamer is used to abrade the glenoid until the subchondral plate is reached, typically about 5 mm. Excessive reaming is avoided. In cases of severe glenoid bone deficiency or deformity, the circular reamer will often not be flush with the glenoid and unreamed areas are abraded with a burr. The central peg hole is drilled to 8 mm and small peripheral drill holes are made using the threaded guidewire to obtain a complete bleeding bone surface. The goal of the glenoid preparation is to reach cancellous bleeding bone to provide an environment for bone graft incorporation and healing. The baseplate and angled bone graft are then impacted into the center hole, with care taken to orient the bone graft appropriately with the defect. Baseplate fixation is performed first using non-locking compression screws in the superior and inferior holes directed parallel to the central post.

Once solidly compressed, preferential tightening of the screws can allow minor modifications in the baseplate tilt. Convergent locking screws are placed in the anterior and posterior baseplate holes. Finally, the glenosphere is fixed to the baseplate with a morse taper and countersunk screw.

Alternative techniques for harvesting and securing humeral head autograft have been described, both in the setting of anatomic and in the setting of reverse shoulder arthroplasty. One commonly used alternative technique involves either in situ or back table preparation of humeral head autograft contoured to fill the bone defect and fixation of the graft with K-wires prior to reaming and baseplate implantation. The proposed benefit of this technique is the ability to retain the general shape of the humeral head to fit the defect. This technique requires more free-hand preparation of the graft and may be less reproducible than the technique by Boileau described above.

The results of humeral head autograft for glenoid bone loss in the setting of RSA have yet to be established in the literature. Boileau et al have published good results using this technique (Bio-RSA) for patients without glenoid bone loss. Following 42 patients for a minimum of 2 years, they reported improvement in Constant-Murley...
score from 31 to 67. Radiographic analysis showed complete graft incorporation in 98% of patients. No graft resorption or glenoid loosening was observed during the short-term follow-up. Scapular notching occurred in only 19% of patients, as compared with the 50% to 90% reported in the literature.49 Although results of the angled Bio-RSA technique (described above) to address glenoid bone loss have yet to be published, they were recently presented. Boileau et al60 reported the results for 54 patients with a minimum of 2 years of follow-up treated with angled Bio-RSA for glenoid deficiency. This included patients with horizontal (Walch B2/C) and/or vertical (Favard E2/E3/E4) plane bone defects. Patients were evaluated clinically and with serial radiographs and CT scans. Clinical outcomes revealed improvement in Constant-Murley score from 31 preoperatively to 68 postoperatively and significant improvement in all range of motion measurements. Most notably, active forward elevation improved from 85° to 148°. Analysis of the radiographic results revealed average version correction of 10° in patients with a horizontal plane defect (Walch B2/C), with average preoperative retroversion of 21.1° and postoperative retroversion of 10.6°. Average inclination correction in patients with a vertical plane defect (Favard E2/3) was found to be 19°, with average preoperative reverse shoulder angle of 60.9° and postoperative reverse shoulder angle of 79.9°. Computed tomography evaluation revealed 98% graft incorporation, and the rate of scapular notching was 25%. Although the results of long-term follow-up are needed, these findings support the use of the asymmetric humeral head autograft to address glenoid bone loss at the time of RSA.

Iliac Crest Autograft

In situations where humeral head autograft is unavailable (revision arthroplasty) or insufficient (massive uncontained defects), tricortical iliac crest autograft can be used. The authors’ preferred technique for harvesting and contouring the iliac crest has been described by Norris et al.54 This technique involves implanting the long peg baseplate (25 or 30 mm) directly on the crest prior to harvesting the bone graft (Figures 9A-C). The benefit of this strategy is immediate, solid fixation of the baseplate to the tricortical iliac crest autograft. After the bone is harvested using an osteotome or oscillating saw, it is contoured to fill the glenoid defect and the baseplate bone graft construct is fixed to the native scapula (Figures 9D-F). This technique is especially useful in revision cases with cavitory bone loss.

Kelly et al61 have published the results of this technique for 12 patients as part of a larger series of 30 revision RSAs. Constant and American Shoulder and Elbow Surgeons scores improved significantly, and 80% of patients were satisfied or very satisfied, according to the authors’ criteria.61 Neyton et al62 reported their findings regarding 9 RSAs using iliac crest autograft, 6 of which were revisions. The technique used for harvesting and fixation of the bone graft was variable and different from that described by Norris et al.54 At 2-year follow-up, 5 patients had no pain (visual analog scale score, 0 out of 10), 3 patients had moderate pain (visual analog scale score, 2 to 5 out of 10), and 1 patient had significant pain (visual analog scale score, 8 out of 10). All patients could elevate their arm at least 90°. According to the authors’ criteria, 4 patients were very satisfied, 3 were satisfied, and 2 were disappointed. No evidence of component loosening or graft failure was found.62

Allograft

Allograft can be used in place of or in combination with autograft for large glenoid defects encountered during RSA. The patient and/or the surgeon may choose to avoid the morbidity associated with harvesting iliac crest bone and elect to use allograft. Although rare, previous surgeries or body habitus may also preclude use of iliac crest autograft.

The strategies and surgical techniques for preparing, contouring, and implanting allograft with the baseplate are similar to those described above with autograft. When selecting allograft, the authors’ current preference is to use femoral neck because it has dimensions that mimic the native glenoid.58 Bateman and Donald66 published their results for 5 patients who underwent single-stage glenoid bone grafting and RSA using a hybrid graft including autograft and femoral neck allograft. With a minimum follow-up of 1 year and CT evaluation, they reported complete graft incorporation in all cases and no evidence of baseplate loosening, but no pain or functional outcomes were reported. Although studies specifically examining the use of femoral neck allograft are limited, the authors have had success using this technique for glenoid bone loss with RSA (Figure 10).

CONCLUSION

Glenoid bone loss is a challenging problem that is frequently encountered during RSA. Failure to identify and address glenoid bone loss can lead to improper baseplate positioning and predispose patients to complications and failure of RSA. Surgeons performing RSA should feel comfortable with the preoperative assessment of glenoid bone loss and be familiar with the surgical strategies to address the bone loss at the time of RSA.

REFERENCES


3. Alentorn-Geli E, Guirro P, Santana F, Tor-


42. Hendel MD, Bryan J, Barsoum WK, et


