SUBSPECIALTY PROCEDURES

BONY INCREASED OFFSET-REVERSED SHOULDER ARTHROPLASTY (BIO-RSA)

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Introduction

Bony increased offset-reversed shoulder arthroplasty (BIO-RSA) is an effective and safe means of achieving lateralization of the prosthetic center of rotation in reverse shoulder arthroplasty.

Reverse shoulder arthroplasty is an effective treatment, relieving pain and restoring function, for a wide variety of pathological conditions affecting the shoulder¹. While cuff tear arthropathy remains the classic indication for reverse shoulder arthroplasty, it can be equally well employed to treat symptomatic irreparable massive rotator cuff tears, inflammatory arthritis, tumors, prosthetic failure, as well as traumatic and posttraumatic etiologies. To overcome weak or absent rotator cuff musculature, Grammont, in pioneering the design of modern reverse arthroplasty, cited 2 main biomechanical principles: (1) medialization of the center of rotation and (2) lowering of the humerus^{2,3}. These allowed for an increase in the tension on the deltoid muscle, improving its mechanical advantage in providing shoulder elevation, while reducing the torque on the glenoid component.

With increasing clinical experience, it has become apparent that medialization of the prosthetic center of rotation results in a number of undesired effects. Humeral impingement on the scapula can result in notching inferiorly, restricted internal rotation due to anterior impingement, and reduced abduction due to acromial impingement⁴. Medialization may also lead to a higher risk of dislocation because of diminished soft-tissue tension and an altered appearance of the shoulder with loss of contour, which may be an aesthetic concern for the patient. To avoid or minimize these issues, lateralization of the prosthetic center of rotation has been advocated. In the context of reverse total shoulder arthroplasty (TSA), lateralization refers to moving the center of rotation lateral relative to that in the classic medialized design of reverse TSA. The prosthetic center of rotation remains medialized in comparison with the native shoulder.

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Lateralization may be achieved on either the glenoid or the humeral side using lateralized metallic prosthetic components⁵ (Fig. 1). With metallic lateralization, a glenosphere with a long neck is implanted onto the native glenoid surface. In doing so, the prosthetic center of rotation lies lateral to the interface of the glenoid prosthesis and the scapular bone. This leads to increased torque at the prosthesis-bone interface, which may result in a higher rate of glenoid prosthetic loosening. Our preference is to achieve a biological glenoid lateralization by placing a bone graft on the glenoid surface, effectively lengthening the scapular neck, while maintaining the center of rotation at the interface between the glenoid prosthesis and scapular bone⁶.

Fig. 1

Figs. 1-A, 1-B, and 1-C Classic Grammont-design reverse shoulder arthroplasty. (Reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67.) **Fig. 1-A** The medialized center of rotation results in potential scapular impingement (yellow asterisk) and notching. **Fig. 1-B** Prosthetic metallic lateralization using a lateral-offset glenosphere. Note the center of rotation (blue asterisk) is lateral to the scapular bone. **Fig. 1-C** Biological osseous lateralization achieved via BIO-RSA. The center of rotation is on the grafted glenoid surface at the interface with the glenoid baseplate.

Indications & Contraindications

Indications

- Cuff tear arthropathy (Hamada grades IVa and IVb)^{1,7} (Table I).
- Massive irreparable rotator cuff tears.
- Inflammatory arthritis.
- Glenohumeral osteoarthritis with associated rotator cuff tear.

TABLE I Hamada Classification System⁷

Hamada Grade	Description
I	Massive rotator cuff tear, normal acromiohumeral distance (AHD)
II	Massive rotator cuff tear with AHD $\leq$ 5 mm
III	Acromiohumeral arthritis with erosion of the acromion due to superior migration (acetabularization)
IVa	Massive rotator cuff tear with glenohumeral arthritis but without acetabularization
IVb	Massive rotator cuff tear with glenohumeral arthritis and with acetabularization
V	Associated humeral head osteonecrosis

Contraindications

- Hamada grade-V cuff tear arthropathy with cephalic collapse.
- Humeral head osteonecrosis.
- Failed hemiarthroplasty or TSA.
- Glenoid unsuitable for implantation of a baseplate because of severe deformity or inadequate bone stock.
- As deltoid function is critical to reverse TSA, patients with a nonfunctional deltoid muscle because of neurological injury or prior surgery are not suitable for this technique.

(Note that, for the first 3 contraindications, there is no suitable bone graft available as the humeral head has collapsed, has become necrotic, or has already been removed during implantation of a humeral prosthesis. BIO-RSA can still be performed for these indications if the bone graft is harvested from the iliac crest or if a synthetic bone graft is used.)

Step 1: Preoperative Planning

Confirm the indication for surgery and obtain radiographs and 3-dimensional (3D) imaging (computed tomography [CT] or magnetic resonance imaging [MRI] scans) to confirm the suitability for a BIO-RSA.

- Ensure that nonoperative treatments, such as injections, analgesia, and physiotherapy, have been exhausted.
- Confirm that nonprosthetic treatments, such as rotator cuff repair, biceps tenotomy, or tenodesis, are not appropriate.
- Obtain good-quality radiographs. When the etiology is cuff tear arthropathy, calculate the acromiohumeral distance and assign the Hamada grade.
- Obtain 3D (preferably CT) imaging to confirm the adequacy of the humeral head bone for harvesting of autograft and suitability of the glenoid bone to accept a baseplate. The glenoid morphology is established in both the axial plane (Walch classification⁸) and the vertical plane (Molé and Favard classification⁹).

Step 2: Patient Positioning and Surgical Approach (Video 1)

With the patient in the beach-chair position, approach the shoulder via a standard deltopectoral approach.

- Perform the surgery with the patient under general anesthesia and regional anesthetic block.
- Place the patient in the beach-chair position.
- Perform a standard deltopectoral approach, protecting and moving the cephalic vein laterally.
- Tag the subscapularis and detach any remaining fibers directly from the osseous insertion at the lesser tuberosity.
- If the long head of the biceps tendon remains present, detach it from its origin at the supraglenoid tubercle and perform a soft-tissue tenodesis by suturing the tendon to the transverse humeral ligament, which forms the roof of the bicipital groove.

Video 1 Video of Angled BIO-RSA for severe and multiplanar glenoid bone deformity.

Step 3: Harvesting of Humeral Graft and Initial Humeral Preparation

Dislocate the humeral head anteriorly and use the instrumentation to harvest a 29-mm fully cancellous graft of desired thickness from the humeral head.

- BIO-RSA is designed to be carried out using the Aequalis Reversed instrumentation and glenoid components (Wright Medical).
- Dislocate the shoulder joint and translate the humeral head anteriorly.
- Place the 155° humeral guide at the summit of the humeral head and set the version by placing the version rod parallel to the forearm axis.
- Using the guide, place the 2.5-mm guidewire into the humeral head (Fig. 2-A).
- Using the bell saw, contour the humeral head to a flat surface until subchondral bone is reached.
- Then use the bell saw to harvest a cylinder of bone 29 mm in diameter (Fig. 2-B).
- Drill a central hole into the graft by passing the 8-mm cannulated drill over the guidewire (Fig. 2-C).

Fig. 2-A

Fig. 2-B

Fig. 2-C

Figs. 2-A, 2-B, and 2-C Preparation of the humerus. **Fig. 2-A** The humeral head has been translated anteriorly, and with the 155° humeral guide positioned on the humeral head, a 2.5-mm threaded guidewire is being inserted into the humeral head. Note the version rod at the top left of the image, which is positioned parallel to the forearm. **Fig. 2-B** The bell saw is advanced onto the humeral head. (Reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67.) **Fig. 2-C** The humeral head has been reamed with the bell saw to a flat surface and a cylindrical disc of bone has been prepared. An 8-mm central hole has been drilled in the graft, matching the diameter of the central peg of the glenoid baseplate. (Reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67.)

- Use the cutting guide to harvest the desired thickness of the graft (Figs. 3-A and 3-B).
- Use a 10-mm graft for a 36-mm glenosphere and 7 mm for a 43-mm glenosphere.
- Insert the disc of pure cancellous bone along the lengthened central peg of the 29-mm-diameter glenoid baseplate and place the construct on a wet sponge securely on a back table (Fig. 3-C).
- If the cancellous bone graft is not of sufficient quality to function as a structural bone graft, one can proceed with a conventional medialized-design reverse TSA or alternatively, using the same instrumentation, a cylinder of bone graft can be harvested from the ipsilateral iliac crest.

Fig. 3-A

Fig. 3-B

Fig. 3-C

Figs. 3-A, 3-B, and 3-C Humeral graft harvesting. (Reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]: 2558-67.) **Figs. 3-A and 3-B** The cutting guide has been positioned (**Fig. 3-A**), and in this case, as a 36-mm glenosphere will be implanted, a graft thickness of 10 mm (**Fig. 3-B**) is used.

Fig. 3-C The disc of cancellous bone has been placed on the central peg of the baseplate, which itself is mounted on the prosthesis holder.

Step 4: Glenoid Exposure, Preparation, and Prosthetic Implantation

Carefully and meticulously expose and prepare the glenoid for prosthetic implantation.

- Place the 29-mm circular glenoid guide flush with the inferior border of the glenoid.
- In cases where the glenoid surface is flat in the horizontal plane, insert the 2.5-mm threaded wire into the glenoid vault with a 10° inferior tilt, to allow for slight inferior tilt of the baseplate and glenosphere.
- If eccentric superior erosion of the glenoid is encountered, such as may occur in the setting of rheumatoid arthritis, insert the guidewire at 0° such that reaming will restore the glenoid to a flat surface in the horizontal plane.
- Using the 29-mm reamer, flatten the glenoid surface until the subchondral plate is reached.
- Drill the central hole to 8 mm over the guide pin with the 8-mm cannulated reamer.
- In the superior portion of the glenoid, where the bone is more densely corticated, use the 2.5-mm threaded guide-pin to drill holes to achieve a complete bleeding bone surface (Fig. 4-A).
- Impact the baseplate with the 25-mm central peg and mounted graft into the central hole (Figs. 4-B and 4-C).
- Obtain rigid fixation using 2 convergent 4.5-mm compression screws and 2 divergent 4.5-mm locking screws.
- Place the locking screws superiorly to engage the coracoid base and inferiorly to engage the scapular pillar, which is a condensation of bone at the lateral aspect of the scapula extending downward from the inferior margin of the glenoid (Fig. 4-D).
- Impact the appropriately sized glenosphere onto the baseplate and tighten the countersunk set screw.
- The largest-size glenosphere that can be accommodated is preferred, but typically a 36-mm glenosphere is implanted in female patients, while a 43-mm glenosphere, if accommodated, is used in male patients.

Fig. 4-A

Fig. 4-B

Fig. 4-C

Fig. 4-D

Figs. 4-A through 4-D Glenoid exposure, preparation, and prosthetic implantation (Reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67.) **Fig. 4-A** The glenoid has been reamed to the level of the subchondral bone inferiorly with a 29-mm reamer. The 2.5-mm guide-pin has been used to create multiple perforations in the harder superior part of the glenoid. **Fig. 4-B** The glenoid baseplate used for BIO-RSA is shown alongside a standard baseplate. Note the lengthened central peg (25 mm vs. 15 mm for the standard prosthesis).

Fig. 4-C The cancellous bone graft mounted on the baseplate and prosthesis holder prior to implantation.

Fig. 4-D The orientation of the baseplate screws is shown. The superior and inferior screws are variable-angle locking screws to allow engagement of the coracoid base superiorly and the scapular pillar inferiorly.

Step 5: Humeral Preparation and Prosthetic Implantation

Prepare and implant the humeral prosthesis as per the standard surgical technique described for implantation of the Aequalis Reversed prosthesis¹⁰.

- Translate the humerus anteriorly.
- Identify the humeral entry point at the summit of the head and reinsert the starter awl and then the cutting block into the medullary canal.
- Establish the humeral retroversion using the retroversion rod on the cutting block, referencing off the forearm axis. Resect the remainder of the humeral head with the 155° guide.
- Ream the metaphysis to either 36 or 43 mm, depending on the chosen size of the glenosphere.
- Sequentially ream the diaphysis until diaphyseal cortical bone is encountered.
- Place high-tensile-strength transosseous sutures in the humeral metaphysis for later repair of the subscapularis.
- Assemble the humeral trial prosthesis and perform a reduction with trial polyethylene inserts to confirm adequate soft-tissue tension and prosthetic stability.
- Assemble the definitive humeral component, which may be cemented or uncemented, and implant, using the polyethylene trials to select the appropriate thickness of polyethylene insert. In most cases, a polyethylene insert of >6 mm is not needed as the lateralization enhances prosthetic stability and soft-tissue tension.
- Insert the definitive polyethylene component, reduce the prosthesis, repair the subscapularis, irrigate the joint, and close the wound in layers.

Step 6: Postoperative Management

Postoperative management is the same as that for a nonlateralized reverse prosthesis, with no alteration in rehabilitation required.

- A sling is worn for the first 4 weeks after surgery.
- Have the patient commence self-directed rehabilitation with pendulum exercises on the first postoperative day. Patients are asked to carry out 15 minutes of exercises, 4 times daily.
- Patients are allowed to remove their arm from their sling for sedentary activities of daily living.
- Formal rehabilitation under physiotherapist supervision is commenced at 4 weeks postoperatively.
- Driving is permitted at 6 weeks postoperatively.
- Heavy lifting is prohibited for 12 weeks to allow incorporation of the glenoid bone graft.
- A return to all preoperative activities is expected at 3 to 6 months after surgery.

Results

In our original series of 42 patients with a minimum follow-up of 2 years (mean, 28 months), the glenoid bone graft incorporated completely in 41 patients and partially in 1 patient (Fig. 5)⁶. No patient had glenoid loosening at the time of follow-up. Patient satisfaction was high, with 32 of 42 achieving good or excellent adjusted Constant-Murley scores. Inferior scapular notching was seen in 8 patients and was more than Grade 2 in only 1 patient¹¹. There were no episodes of prosthetic instability, and no patient underwent revision surgery for any reason.

We have also used an Angled BIO-RSA (Tornier/Wright) to correct complex glenoid bone loss or erosion and to restore more anatomic inclination and retroversion (Figs. 6 and 7).

Fig. 5-A

Fig. 5-B

Fig. 5-C

Fig. 5-D

Fig. 6

Fig. 7

Figs. 5-A through 5-D Healing of bone graft. **Figs. 5-A and 5-B** The concept of BIO-RSA is to create a scapula with a long neck in order to keep the center of rotation at the level of the scapula. Once the bone graft has healed to the native glenoid, this allows avoiding excessive shearing loads on the glenoid implant. Additional benefits are better shoulder cosmesis, increased shoulder stability, and increased range of motion of the polyethylene cup around the glenosphere and minimal scapular notching. (Reproduced, with modification, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67. Reproduced with permission.)

Figs. 5-C and 5-D CT-scan axial and coronal cuts demonstrating perfect healing of the bone graft with the native scapula and minimal or no scapular notching. (Figure 5-C reproduced, with permission, from: Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res. 2011 Sep;469[9]:2558-67.)

Fig. 6 The Angled BIO-RSA concept consists of harvesting a trapezoid-shaped bone graft to correct baseplate version and inclination, in addition to providing lateralization.

Fig. 7 The RSA angle (or reverse shoulder arthroplasty angle) is used to measure the inclination of the lower portion of the glenoid surface relative to the tangent to the inferior rim of the glenoid and orthogonally to the supraspinatus fossa line. A trapezoid-shaped bone graft (Angled BIO-RSA) allows implantation of the central post parallel, and the sphere orthogonal, to the supraspinatus fossa line. (The RSA angle becomes close to zero.)

Pitfalls & Challenges

- Be careful to identify and protect the axillary nerve, which is particularly at risk when releasing the capsule and triceps origin at the inferior aspect of the glenoid.
- When reaming the glenoid, be careful not to start the reamer on the glenoid surface as the sudden torque at the onset of reaming may be sufficient to fracture the glenoid.
- To avoid iatrogenic intraoperative humeral fracture, do not prepare the humeral shaft, with the exception of graft harvesting, until after the glenosphere has been inserted.
- Always carry out a trial reduction to confirm prosthetic stability, adequate soft-tissue tension, and the absence of an impingement, which could lever out the prosthesis or serve to generate particulate debris.

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