SUBSPECIALTY PROCEDURES

PATIENT-MATCHED IMPLEMENTATION FOR
REVERSE TOTAL SHOULDER ARTHROPLASTY

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Introduction

Three-dimensional (3D) preoperative planning and patient-specific instrumentation (PSI) improve accuracy of glenoid component implantation in reverse shoulder arthroplasty.

Reverse arthroplasty has been proven to be a successful treatment for end-stage cuff tear arthropathy in elderly patients¹⁻⁶. However, correct positioning and fixation of the glenoid component remain one of the most important challenges of the procedure that will determine early and long-term results^{2,7-9}. Variable glenoid vault anatomy and bone stock may compromise the ultimate position and fixation of the glenoid component^{9,10-14}.

The use of 2D imaging and currently available surgical instruments has been shown to be imprecise for the correction of severe glenoid deformity^{15,16}. Several authors have reported better accuracy of glenoid component positioning using 3D imaging and patient-specific instrumentation in cadaveric and clinical studies^{15,17-21}.

Indications & Contraindications

Indications

- Rotator cuff tear arthropathy
- Irreparable rotator cuff tear
- Glenohumeral arthritis with biconcave glenoid
- Three or 4-part proximal humeral fracture in an elderly patient
- Failed hemiarthroplasty or total shoulder arthroplasty

Contraindications

- Infection
- Deltoid paralysis
- Acromion deficiency
- Severe glenoid bone loss

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Step 1: Preoperative Virtual 3D Planning (Video 1)

Use a 3D software tool for virtual preoperative planning of glenoid component implantation.

- Use the 3D virtual surgery tool (Zimmer Biomet PSI shoulder planner software), which is based on the patient's preoperative computed tomography (CT) scan, to visualize and optimize preparation of the glenoid bone surface and the position and fixation of the implant and screws.
 - Assess the patient's native glenoid anatomy and bone stock. In the patient shown in Video 1, the glenoid inclination is $+11.8^\circ$ and the version is -18.4° . The patient has an important glenoid deformity that is mostly situated at the superoposterior quadrant due to longstanding eccentric loading of the glenoid by the superiorly migrated and deformed humeral head.
 - Virtually position the baseplate as low as possible on the glenoid surface in neutral inclination and version.
 - Assess the central peg to determine the correct position in all 3 planes within the glenoid vault. In the patient shown in Video 1, a standard 15-mm central peg is most suitable.
 - To achieve optimal glenoid component seating, the glenoid bone should be reamed to remove 6 to 10 mm of bone from the anteroinferior quadrant. This allows good ($>80\%$) contact with the baseplate. Removing more bone to improve seating would compromise the glenoid bone stock and overmedialize the component.
 - Plan the desired orientation of the screws for optimal fixation. For the patient in Video 1, the optimal length of the superior and inferior screws is 36 mm, allowing for bicortical bone purchase without danger of damaging the surrounding neurovascular structures and soft tissues.

Video 1 Preoperative virtual planning of the glenoid component implantation.

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

Place the patient in a semi-beach-chair position and perform a standard deltopectoral approach.

- After induction of general anesthesia with an interscalene catheter for postoperative pain control, place the patient in a semi-beach-chair position (Fig. 1). Use a headrest that allows for the superior part of the table to be removed.
- Place a cushion under the spine and the medial border of the scapula to raise the affected side and thereby improve intraoperative exposure of the glenoid.
- The shoulder should be readily circumferentially accessible with the arm positioned on an arm rest.
- Make a 10-cm skin incision lateral to the coracoid process and perform a standard deltopectoral approach, leaving the cephalic vein lateral in the interval.
- Place a Hohmann retractor on the coracoid process and a deltoid retractor under the deltoid muscle to improve visualization.
- Release the upper border of the pectoralis major tendon and find the long head of the biceps tendon. Then perform a tenodesis of the long head of the biceps.
- After placing stay sutures, peel off the subscapularis tendon from the humerus close to its insertion.
- Gently dislocate the humeral head anteriorly. Note the lack of intact rotator cuff in the case example shown in Video 2.

Fig. 1

Video 2 Standard deltopectoral approach.

Fig. 1 Positioning of the patient in a semi-beach-chair position. The shoulder is circumferentially accessible, and a cushion is positioned under the spine and the medial border of the scapula to improve glenoid exposure.

Step 3: Humeral Preparation (Video 3)

Prepare the humeral side for implantation of the humeral component using standard instrumentation.

- To facilitate access to the humeral canal extend the shoulder back and externally rotate the arm.
- Find the entry point of the humeral canal, which is approximately 1 cm medial and posterior to the bicipital groove.
- Begin manually reaming the humeral canal. Use progressively larger reamers in 1-mm increments until resistance is felt from cortical contact in the canal.
- Remove the T-handle but leave the last reamer in the canal to interface with the humeral head cutting guide.
- Assemble the humeral head cutting guide for a left or right configuration. Line up the alignment rods with the forearm to assess the retroversion. Retroversion of 10° is most suitable.
- Use an oscillating saw to resect the humeral head. Then remove the cutting block.
- Attach the T-handle to the proximal part of the reamer and manually ream the proximal part of the humerus in 10° of retroversion until the reamer is flush with the proximal-lateral edge of the canal opening.
- Insert the trial humeral component in the same orientation as the last reamer.

Video 3 Humeral preparation.

Step 4: Glenoid Exposure and Preparation (Video 4)

Expose the glenoid and prepare the glenoid surface for component implantation.

- Dislocate the prepared humerus posteriorly.
- Place retractors behind the posterior and anterior aspects of the glenoid rim and place a small Hohmann retractor on top of the glenoid fossa.
- Release the anteroinferior aspect of the capsule and the long head of the triceps inferiorly.
- Remove the remaining cartilage and remnants of the labrum.
- Specifically prepare the anterosuperior corner of the glenoid rim. This area must be free of interfering soft tissue to allow seating of the PSI pin guide. At this time, compare the native glenoid with the PSI bone model to ensure that all of the soft tissue has been removed and that the PSI pin guide will have a good fit on the glenoid.

Video 4 Glenoid preparation.

Step 5: Glenoid Preparation and Implantation of the Glenoid Baseplate Using 4 PSI Guides (Video 5)

Use the 4 PSI guides to prepare the glenoid for component implantation according to the preoperative plan.

- Use the 4 PSI guides to execute the preoperative planning for glenoid component implantation. These include (1) a pin guide for insertion of the central pin in the desired version and inclination; (2) a ream guide, which sets the reaming angle and depth; (3) a roll guide for guidance of component rotational orientation and screw entry points; and (4) a screw guide, which provides the drill direction to achieve the planned screw orientation and length (Fig. 2).
- Place the first PSI pin guide on the surface of the glenoid; it should sit tightly on the glenoid surface and be locked in place once it is positioned correctly. The hook should be on the anterosuperior quadrant of the glenoid, and the opening along the bushing should face the posterior side of the glenoid. Hold the PSI pin guide tightly with your fingers and insert the inferior 2.5-mm pin through the central hole of the PSI guide until the depth mark on the pin meets the top of the metal bushing. Then insert the superior 2.5-mm pin through the superior hole in the same manner.
- Remove the bushings and PSI pin guide. Check the insertion points of the 2 pins with the planned position on the bone model.
- Create the pilot hole for the glenoid reamers using the 6-mm cannulated drill-bit. Then use the baseplate reamer with the PSI ream guide to prepare the glenoid surface. Ream until the subchondral bone is exposed inferiorly, matching the preoperative plan, and until the PSI ream guide reaches the lateral end of the cannulated straight driver. Compare the reamed glenoid surface with the image provided in the preoperative plan. Remove the inferior pin and further dilate the baseplate pilot hole using a 7.5-mm drill-bit.
- Use the PSI roll guide to insert the definitive baseplate component in the preoperatively determined correct orientation. This will further determine the insertion points and orientation of the locking screws. Strike the baseplate inserter with a mallet until the back of the component is completely flush with the prepared surface. In the case shown in Video 5, there is a small gap behind the superior part of the component, as expected on the basis of the preoperative 3D planning. This small gap is filled with cancellous autograft from the humeral head.
- Finally, use the screw PSI guide to drill the screw pilot holes in the exact orientation as was planned preoperatively. Then insert superior and inferior locking screws and locking caps.

Fig. 2

Video 5 PSI-guided glenoid component implantation.

Fig. 2 PSI guides for execution of the preoperatively planned implantation: (1) pin guide for placement of the central pin, (2) ream guide for controlled glenoid reaming, (3) roll guide for rotation orientation and screw insertion point, and (4) screw guide for drill guidance of pilot holes. 5 = bone model for perioperative visual reference.

Step 6: Definitive Implantation of the Components and Reduction (Video 6)

Implant the glenosphere and humeral component and reduce the prosthesis.

- Impact the glenosphere onto the baseplate and check if it is well seated and stable.
- Implant the definitive humeral stem in 10° of retroversion.
- First use a trial insert and test stability and mobility after trial reduction.
- Finally, impact the polyethylene liner and reduce the definitive components.
- If possible, repair the subscapularis to the humerus in 30° of external rotation using a transosseous technique with heavy nonabsorbable sutures in a Mason-Allen configuration.
- Thoroughly irrigate the wound and close it in a layered fashion. We do not routinely use drains.
- Figure 3 shows a glenoid component in an excellent position 6 weeks postoperatively.

Fig. 3

Video 6 Final implantation and reduction.

Fig. 3 Postoperative radiograph made 6 weeks after surgery showing a good position of the reverse prosthesis. The glenoid component is well-positioned and fixed in the glenoid vault.

Step 7: Postoperative Rehabilitation Protocol

Start passive and active-assisted exercises immediately, and begin muscle strengthening and active exercises at 6 weeks.

- The patient wears an abduction brace for 4 weeks for comfort and protection.
- Start immediately with pendulum exercises, scapular muscle isometric exercises, and passive and active-assisted exercises while avoiding combined shoulder extension and external rotation of >30° and internal rotation behind the back during the first 6 weeks.
- Start muscle strengthening and active exercises at 6 weeks.

Results

A recent prospective, comparative study assessed the influence of 3D preoperative planning and PSI guidance of glenoid component positioning in total shoulder arthroplasty and reverse shoulder arthroplasty¹⁸. In this study of 36 shoulder arthroplasties (12 total and 24 reverse), 18 (6 total and 12 reverse) had been performed with 3D planning and PSI guidance to position the central guide pin for glenoid component implantation and 18 had not. Nine shoulders had severe distortion of the glenoid anatomy as a result of wear or a prior operative procedure. After the total shoulder arthroplasties, inclination of the glenoid component (measured, by two observers, as the angle between the glenoid baseplate and the supraspinatus fossa floor on postoperative radiographs) averaged $74^\circ \pm 9^\circ$ in the group in which PSI had been used and $86^\circ \pm 12^\circ$ in the group in which it had not. The respective values were $83^\circ \pm 7^\circ$ and $90^\circ \pm 17^\circ$ after the reverse shoulder arthroplasties. The likelihood of extreme inclination of the glenoid component was found to be higher when PSI had not been used than when it had been used ($p < 0.001$ and 0.02 for total and reverse shoulder arthroplasty, respectively). No complications related to the PSI procedure were reported.

In conclusion, 3D preoperative computer planning coupled with patient-specific and implant-specific instrumentation may allow the shoulder surgeon to better define preoperative deformities, select the optimal implant position and fixation, and then accurately execute the plan at the time of surgery. This novel technique may increase the accuracy and reproducibility of shoulder reconstructive procedures, but future clinical outcome studies are needed to determine whether this can positively affect long-term functional outcomes.

Pitfalls & Challenges

- Preoperatively, the surgeon should take enough time to personally perform the 3D virtual preoperative planning, with which assessment of the patient's anatomy is completely different from assessments performed with standard imaging (Figs. 4-A and 4-B).
- Perform adequate soft-tissue releases and meticulously expose the glenoid surface.
- Use the bone model and preoperative planning images to check the executed procedure with the planned surgical steps.
- Positioning of the first PSI pin guide is vital for the further preparation of the glenoid surface. This may initially increase the operative time needed to complete the surgical procedure.
- Apply bone graft to the glenoid if the primary stability of the glenoid component is doubted.

Fig. 4-A

Fig. 4-B

Figs. 4-A and 4-B Preoperative anteroposterior radiograph (**Fig. 4-A**) and computed tomography axial image (**Fig. 4-B**) showing the left shoulder of a patient with chronic cuff tear arthropathy, superior migration of the humeral head, and associated deformity of the humeral head and glenoid.

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