60 Convertible Humeral Stem: Anatomic to Reverse Arthroplasty

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Abstract
This chapter details one of the main advancements in revision shoulder arthroplasty. Platform shoulder systems minimize patient morbidity by allowing a more straightforward conversion from an anatomic total shoulder arthroplasty to a reverse total shoulder arthroplasty without the need to exchange a well-fixed, well-positioned humeral stem.

Keywords: *platform shoulder system, convertible shoulder system, revision total shoulder arthroplasty, total shoulder arthroplasty, reverse total shoulder arthroplasty*

60.1 Goals of Procedure

Platform shoulder arthroplasty systems allow for conversion of an anatomic total shoulder arthroplasty (ATSA) to a reverse total shoulder arthroplasty (RTSA) without necessitating the removal of a well-fixed, well-positioned humeral stem and the associated risks of proximal humeral bone loss. Failed ATSA resulting in instability due to either progressive rotator cuff failure or component malpositioning may not be amenable to an anatomic revision procedure. An RTSA establishes a stable fulcrum to optimize shoulder biomechanics and provides inherent stability. Platform shoulder systems provide versatile options for preserving the humeral stem, which simplifies the revision procedure, minimizes patient morbidity, and conserves humeral bone stock while providing pain relief, improved functionality, and shoulder stability.

60.2 Advantages

Converting from an ATSA to an RTSA while preserving a well-fixed, well-positioned humeral stem avoids the technical challenges and significant morbidity associated with stem exchange. Exchanging either a cemented or uncemented humeral stem is technically challenging and associated with high rates of iatrogenic fracture, loss of proximal humeral bone stock, prolonged operative time, increased blood loss, and neurovascular injury. Furthermore, additional procedures such as humeral shaft corticotomy, strut grafting, and a more extensile approach are often necessary. Patients with a failed ATSA resulting in shoulder instability may benefit from the inherent stability provided by the constraint of an RTSA (**Fig. 60.1**). As these patients are often osteopenic with poor bone quality, converting to an RTSA while preserving the humeral stem can preserve valuable bone stock, minimize morbidity, optimize function, and provide substantial pain relief.

60.3 Indications

Indications for converting from a failed ATSA to an RTSA most commonly include instability, component malposition, delayed failure or insufficiency of the rotator cuff, and aseptic loosening of the glenoid. The direction of shoulder instability is often indicative of the underlying pathology. Anterior instability commonly results from subscapularis deficiency, which is among the most commonly encountered problems following shoulder arthroplasty. Anterosuperior instability typically results from progressive rotator cuff failure secondary to either attritional changes or trauma. Rotator cuff deficiency can result in superior migration of the humeral head, which may also contribute to glenoid component loosening. Component malposition is another common indication for revision. Posterior instability may result from component malpositioning whereby the humeral, glenoid, or the combined version is significantly retroverted. Additionally, a stem that is malpositioned too proximally, often secondary to a nonanatomic humeral head resection, may result in pain, limited function, and progressive cuff disease. Finally, aseptic loosening of the glenoid component is a frequent mode of failure in ATSA. Glenoid loosening is often accompanied by instability and attritional rotator cuff disease. Revision to an RTSA is often necessary when the loose component is symptomatic and associated with glenoid bone loss in the setting of a deficient rotator cuff.

60.4 Contraindications

Contraindications for converting from an ATSA to an RTSA with a platform system pertain chiefly to the specific implant and its position. Platform shoulder systems come in two different varieties:

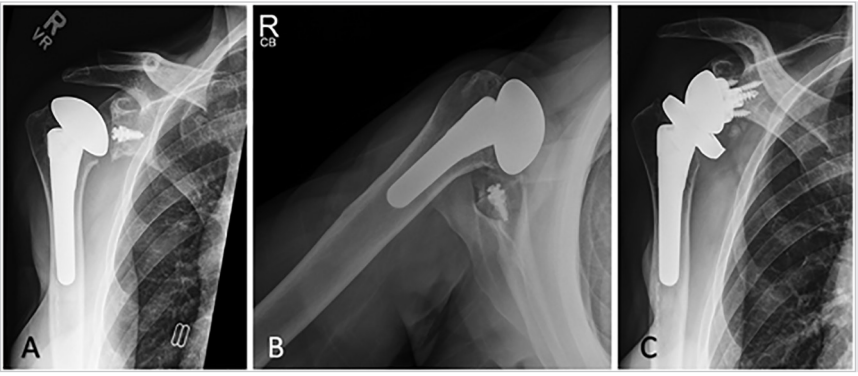

Fig. 60.1 Anteroposterior **(a)** and axillary **(b)** radiographs in a patient with anterior shoulder instability and pain secondary to a subscapularis rupture following total shoulder arthroplasty. Conversion to a reverse total shoulder arthroplasty was performed while retaining the humeral stem **(c)**.

Table 60.1 Types of platform shoulder arthroplasty systems commercially available

In-side or Inlay	On-top or Onlay
Depuy Global Unite (Warsaw, IN) Integra Titan (Plainsboro, NJ) Smith & Nephew PROMOS (Cordova, TN) SMR Lima (Arlington, TX)	Tornier Aequalis Ascend Flex (Stafford, TX) Zimmer-Biomet Comprehensive (Warsaw, IN)[a] Exactech Equinoxe (Gainesville, FL) Lavender Medical UNIC Evolutis (Briennon, France) DJO Turon (Austin, TX) Stryker ReUnion (Mahwah, NJ)

[a]Also has a humeral tray to use in conjunction with a Bio-Modular stem to convert to a reverse total shoulder arthroplasty.

an "In-side" or "Inlay" system or an "On-top" or "Onlay" system. Inlay systems have a modular body that connects to the humeral stem, whereas Onlay systems have no modular component. Rather, the humeral tray connects directly to the stem. Several of the currently available components are listed in **Table 60.1**. The modular body in Inlay systems allows for more flexible optimization of implant height and version. Onlay systems with malpositioned stems (either too proximally or retroverted) may result in unacceptable lengthening of the humerus or persistent instability. Finally, stem retention is obviously contraindicated when the stem is loose or when there is concern for infection.

Contraindications that apply to all revision situations include active infection, axillary nerve deficit, compromised deltoid function, and inadequate glenoid bone stock to support a glenosphere. Indolent infections should always be considered in revision shoulder arthroplasty and unexpected positive cultures frequently occur. *Propionibacterium acnes* is a frequent culprit and presents indolently with pain and may be difficult to culture.

60.5 Preoperative Planning/ Position

60.5.1 History and Physical

Preoperative planning for revision shoulder arthroplasty begins with a detailed history and physical examination. Important aspects of the history address the nature of the patient's symptoms that prompted the initial surgical intervention, postoperative complications (wound issues, dislocation, fracture, etc.), subsequent procedures, and whether a pain-free interval existed postoperatively. Additionally, it is imperative to obtain previous surgical records. This will indicate whether the primary system is convertible and may describe the integrity of the rotator cuff during the index procedure. The presence of inflammatory arthropathy is important to elucidate since this may increase the risk of progressive rotator cuff insufficiency. Physical examination should focus on evaluating for signs of indolent infection, as well as the overall function of the deltoid, with a particular focus on internal and external rotation strength.

60.5.2 Labs and Imaging

Routine labs and imaging studies are part of our standard preoperative evaluation in revision shoulder arthroplasty. A complete blood count (CBC), erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are obtained to evaluate for infection. If the ESR and CRP are elevated, we will typically obtain an image-guided shoulder aspiration and culture with a special attention for anaerobic cultures and P. acnes. In addition to a standard shoulder plain film series, CT is often useful to assess the degree of glenoid bone loss, component version, and deformity. The integrity of the glenoid bone stock may influence the type of implant (i.e., augmented baseplate) and the need for bone graft. Metal subtraction MRI sequencing (MARS) can also be obtained to evaluate the integrity of the rotator cuff.

60.5.3 Patient Positioning

We prefer to position patients in the beach-chair position with the back elevated approximately 40 degrees. A wedge pillow placed underneath the thighs helps facilitate the seated position and provide stability. The patient is positioned with the operative extremity over the lateral aspect of the table, which allows for adequate humeral access during adduction and extension of the extremity. We also place a rolled towel behind the medial border of the scapula, which enhances glenoid exposure. It is critical to assure that the arm can be sufficiently extended to allow for humeral canal access and instrumentation free of interference from the patient's head. With the patient positioned, we routinely perform an examination under anesthesia to assess for forward flexion and external rotation. The patient is then prepped and draped to allow maximum exposure of the extremity. We also routinely use a hydraulic mechanical arm holder to aid in positioning of the extremity during the procedure.

60.6 Operative Technique

60.6.1 Approach

We prefer to use a deltopectoral approach as it is extensile and reliably results in excellent visualization. Most patients will have a previous deltopectoral incision, which can often be utilized. The incision is made from just proximal and lateral to the coracoid process extending toward the deltoid tuberosity. This can be extended distally down the anterolateral aspect of the arm to allow for a brachialis split if a larger exposure is needed. The incision is carried deep to the subcutaneous tissue down to but not through the underlying deltopectoral fascia. Care is taken to identify the cephalic vein, which we tend to laterally as this disrupts less tributaries. Scar tissue often distorts the surgical approach, so it is important to reestablish soft-tissue planes through a combination of electrocautery and blunt dissection. Working from normal tissue planes proximal or distal to the previous dissection helps establish the correct intermuscular plane in the scarred regions.

The deltopectoral interval is then developed through blunt dissection. The pectoralis major is retracted medially, while the deltoid is retracted laterally. The subdeltoid space is often firmly adhered to the lateral aspect of the proximal humeral prosthesis. A finger placed deep to the deltoid and lateral to the humeral component can break up adhesive scar tissue. This step is critical to help mobilize the humerus. Next, we identify the lateral border of the conjoined tendon. The tendon of the pectoralis major is often firmly scarred to the conjoined tendon. We develop this interval through blunt dissection with the arm adducted to minimize the risk of neuropraxia to the musculocutaneous nerve. After mobilization of these layers, we retract the conjoined tendon medially to identify the subscapularis. External rotation of

the arm brings the subscapularis into the field and farther from the axillary nerve. If the subscapularis is present, it can be detached several ways. In a revision setting, we prefer to peel the subscapularis off the lesser tuberosity subperiosteally while preserving maximum tendon length for eventual repair.

A capsulotomy is made with electrocautery while progressively externally rotating, extending, and adducting the arm. This maneuver allows exposure of the medial and proximal aspects of the humeral component while maximizing the distance between our dissection and the nearby neurovascular structures. We do not routinely dissect out the axillary nerve; however, it is imperative to palpate the nerve and perform a "tug test" throughout the procedure to be cognizant of its location. A circumferential exposure of the proximal humeral component can be obtained by releasing any remaining subscapularis or inferior capsule that precludes adequate external rotation. A circumferential release of the subscapularis tendon is performed by excising the underlying capsule to allow for normal tendon excursion for later repair.

60.6.2 Humeral Exposure and Preparation

Retractors are placed to bring the humeral component anteriorly into the operative field. It is often necessary to remove osteophytes, cement, and surrounding soft tissue to provide adequate exposure of the prosthesis. The humeral head component can be removed at this point using various extraction devices to disengage the head from either the stem (Onlay prosthesis) or the modular body (Inlay prosthesis). Following humeral head removal, we routinely send multiple samples to pathology for intraoperative culture and frozen section. The number of neutrophils per high power field can be assessed on the frozen section and is a reasonable indicator for infection. Any greater than 5 neutrophils per high-power field is a cause for concern and may warrant aborting the conversion in lieu of a resection and antibiotic spacer placement.

Onlay prostheses allow for a more direct conversion from an ATSA to an RTSA. Once the humeral head component is disengaged from the stem, the reverse humeral tray can be inserted directly onto the humeral stem without the need for additional reaming of the proximal humeral metaphysis. Most systems have humeral trays with several different offsets and thicknesses, which can be combined with polyethylene liners of various thicknesses to optimize the stability of the implant while minimizing impingement.

The ability to adjust humeral length and version may be more limited with Onlay components. For humeral stems that are malpositioned too proximally, the resulting humeral length and deltoid tension created by the thickness of the humeral tray and polyethylene may preclude stem retention. Overtensioning the deltoid can have deleterious consequences as this results in increased load on the glenosphere and scapular spine, which potentially may result in glenoid component loosening and fatigue fractures of the acromion/scapular spine. Similarly, the humeral version is dictated by the position of the anatomic stem. Some systems have the capacity to adjust the humeral version to a certain degree by modifying the humeral tray. However, this modest adjustment may not be sufficient in cases of excessive retroversion. If the height or version preclude a simple conversion, the anatomic stem needs to be removed.

Inlay prostheses require additional humeral preparation to convert from an ATSA to an RTSA; however, ultimately they have more versatility compared to Onlay components. After removal of the humeral head, the modular body needs to be removed. We prefer to use a flexible osteotome to separate any bony ingrowth between the body of the humeral stem and the proximal humeral metaphysis. Flexible osteotomes are thinner and more maneuverable, ultimately allowing more of the proximal humeral bone stock to be preserved. This step is critical for cemented as well as uncemented components as circumferential separation of the body from the humerus is necessary for safe component removal.

Following removal of the modular body, the overall position of the humeral component needs to be assessed prior to preparing the proximal humeral metaphysis for the reverse body component. If the humeral component is malpositioned too proximally, one can address this in one of two ways: additional resection of the proximal humerus or by adjusting the height of the modular body component. One of the unique benefits of the Inlay system is that additional humeral resection can be performed without interfering with the well-fixed stem distally.

Another benefit of the Inlay prosthesis is that the modular body for the RTSA can be reoriented and therefore is not limited by the humeral version from the index procedure. Prior to reaming, it is often necessary to remove bone from the proximal lateral metaphysis with a rasp or rongeur to avoid conflict with the reamer guide, which may push the components into varus. During reaming, the guide must be collinear to the axis of the humeral stem. While the typical humeral version for ATSA is between 30 and 40 degrees of retroversion, our goal for RTSA is between neutral and 20 degrees of retroversion. Therefore, it is important to preferentially ream more bone anteriorly to achieve the desired version. Once reaming is complete, it is important to debride between the proximal metaphysis and the humeral stem to remove interposed soft tissue, which may potentially obstruct the Morse taper. After preparation of the proximal humerus is complete, a trial reverse body can be placed on to the well-fixed stem.

60.6.3 Glenoid Revision

Glenoid component revision from an ATSA to an RTSA is largely dependent on the glenoid fixation as well as the initial implants used. Glenoid component loosening is a common indication for revision arthroplasty. In these instances, one may have to address issues pertaining to bone loss and component malposition. Preoperative CT is helpful to assess the location and degree of bony insufficiency. We find this particularly useful as it will often direct the need for bone grafting and may influence our choice in baseplate. Certain platform shoulder systems use metal-backed glenoid components, which allow for a straightforward conversion to a glenosphere. However, it is more common to encounter either loose or well-fixed cemented all-polyethylene glenoids.

60.6.4 Glenoid Exposure and Preparation

Revision of the glenoid component starts with obtaining excellent exposure. The humeral component must be protected as

it is mobilized posteriorly. Retractors are placed to expose the glenoid. A thorough circumferential soft-tissue release along the margins of the glenoid is necessary. In particular, a meticulous release of all scar tissue along the anterior and inferior rim of the glenoid is critical to ensure eventual accurate component placement. If the glenoid component is grossly loose, it can often be removed easily along with adherent cement. Well-fixed components can be more challenging; however, the ultimate goal is to remove the component and cement while preserving as much bone as possible.

Removal of the glenoid component is first attempted by separating the component en bloc from the glenoid with an osteotome. It is critical to approach the component parallel to the component–glenoid interface as angulation may result in violation of the glenoid vault and compromise valuable bone stock. If obtaining the ideal starting position is compromised, it is safer to remove the component in a piecemeal fashion. Once the component is removed, the remaining cement can be removed with an osteotome or a rongeur.

It is essential to assess the remaining glenoid bone stock following component and cement removal. The location and degree of bone loss will often dictate further management. Central contained defects are most easily managed with simple bone grafting. These defects do not typically result in problems with fixation since the majority of glenoid baseplates have options for central as well as peripheral fixation. Conversely, large unconstrained defects may require a structural bone graft in order to provide enough mechanical support to allow for adequate baseplate fixation. In these instances, we prefer to use iliac crest bone graft. Finally, for glenoids with asymmetric bone loss, augmented glenoid baseplates provide a good option to optimize fixation and glenosphere position.

The remainder of the glenoid preparation as well as baseplate and glenosphere placement is similar to that of a primary RTSA with a few notable differences. We tend to hand ream the glenoid in order to preserve valuable bone stock. Additionally, for revision situations we are typically more inclined to use a larger central peg with longer peripheral screws for the baseplate and will also frequently use a larger glenosphere. While the use of a larger glenosphere may potentially reduce maximum mobility, it is advantageous for increasing the stability of the prosthesis. We position the glenosphere low on the glenoid with inferior offset and tilt in order optimize function while increasing anterior translation and clearance to prevent notching.

60.6.5 Final Assessment and Closure

Following placement of the final components, it is important to assess overall joint stability, impingement, and range of motion. Joint stability is tested by observing distraction with the shuck test as well as stability throughout the range of motion, particularly with the arm in extension. We evaluate for impingement in abduction and throughout the functional range of motion. The wound is copiously irrigated and closed in a layered fashion. We routinely place a deep drain next to the implant. We also obtain postoperative radiographs of the shoulder and the entire humerus.

60.7 Tips and Pearls/Expert Suggestions

- Preoperative planning is critical, including a thorough history and physical examination.
- Preoperative CT is very useful for detecting and assessing the location and extent of bone loss.
- Routinely send multiple specimens to pathology to evaluate for an unexpected infection. Be prepared to perform a staged resection arthroplasty if the frozen section is suggestive of infection.
- Have a low threshold to remove the humeral stem if retention is not possible without overlengthening the humerus or if there is persistent instability.
- If a cemented stem is loose and needs to be removed, it can be recemented in the previous cement mantle, thereby avoiding the need for complete cement removal.

60.8 What to Avoid

Converting from an ATSA to an RTSA while retaining the humeral stem can be an effective procedure; however, one must be cognizant of its limitations. The main limitation to this procedure is retaining a stem that is malpositioned either proximally or in excessive retroversion. Often this can be corrected to provide a stable joint without overlengthening the humerus. Retaining a well-fixed stem that results in persistent instability or overlengthening of the humerus can have deleterious consequences such as neuropraxia, premature glenoid loosening, and iatrogenic fatigue fracture.

60.9 Complications/Bailout/Salvage

One of the most common situations necessitating a bailout procedure is when the humeral stem cannot be retained due to either unexpected loosening or proximal malposition resulting in overlengthening of the humerus. In both instances, the surgeon must be prepared to extract the stem and perform additional procedures such as a humeral shaft corticotomy if the stem is well fixed and cannot be removed more conservatively. Furthermore, the surgeon must be prepared to deal with intraoperative fracture necessitating fixation and possibly revision with a long humeral stem. Finally, if the intraoperative frozen section is concerning for infection, the surgeon should be prepared to do a staged resection arthroplasty with an antibiotic spacer.

60.10 Postoperative Care

Our postoperative protocol for revision shoulder arthroplasty when using a platform system to convert from an ATSA to an RTSA with retention of the humeral stem is similar to that of a primary RTSA unless it is a complex revision. A deep drain may be left in place for at least 24 hours. We instruct patients to avoid external rotation beyond neutral with their arm at their side. We allow them to perform the Codman pendulum exercises in a sling. By 2 to 3 weeks postoperatively, we allow patients to initiate forward flexion in the scapular plane to approximately 100 degrees.