Revision of Humeral Components in Shoulder Arthroplasty

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Abstract
Revision of a shoulder arthroplasty often requires removal of a well fixed humeral component. Revision of this component can be quite easy in the case of a non-infected platform stem or be very difficult when removal of a well cemented or on-growth stem with distal texturing is required. The purpose of this paper is to provide a series of techniques designed for revision of the humeral component in shoulder arthroplasty.

Revision of the stem can be easy with a non-infected platform stem only requiring exchange of the epiphyseal component. Some stems, usually uncemented, can readily be removed from a proximal only approach. Stems with excellent cement mantles may require a longitudinal only split in the humerus done with minimal stripping of the brachialis. If complete cement removal is needed for infection or there is distal stem on growth, then a vascularized door technique is indicated. These techniques are explained in detail in this manuscript.

Loosening of the humeral component in shoulder arthroplasty is a rare occurrence. However, there are a number of indications for removal of a humeral stem. Unfortunately, in the majority of cases the humeral stem is usually well fixed either with cement or bone on-growth. In the process of removal of a well-fixed stem, the humerus may sustain significant damage. This paper will cover the indications for removal of humeral stems, techniques for removal of stems, and reconstruction of the humerus for revision shoulder arthroplasty. The technique and results of a vascularized humeral-door procedure for removal of a well-fixed stem will also be presented.

Indications
There are multiple indications for removal of a humeral stem in a patient with a dysfunctional shoulder arthroplasty. Probably the most common reason for stem removal is revision for a failed total shoulder arthroplasty or hemiarthroplasty to a reverse total shoulder arthroplasty. Some systems have a common platform stem which does not require removal (unless infected or placed too proud), but most systems do not have this option. Another common reason for stem removal is infection. In the case of infection, not only is it necessary to remove the stem but all the foreign material including cement, cement restrictor, implant, and suture should be removed. Periprosthetic fractures that render the implant unstable represent a small but complex subset of patients who also require stem revision. Finally, primary humeral-implant loosening, which is uncommon and in the majority of cases probably represents an indolent infection, is an indication for revision. In the unusual case of aseptic loosening due to osteolysis a revision may be indicated in the absence of symptoms to decrease the risk of periprosthetic fracture secondary to progressive bone loss.

Methods for Removal of Humeral Stem
Revision of a humeral stem can be relatively easy or highly destructive to the proximal humeral bone stock. Before starting it is very important that the surgeon know the manufacturer of the implanted stem. Some manufacturers have a platform stem, and therefore it is mandatory that the surgeon have that manufacturer’s implants in the operating room so as to not cause unnecessary compromise of the patient’s proximal humerus during removal of a well-fixed stem. It cannot be emphasized enough that patients with a platform stem in place should be revised using compatible components and avoiding

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removal of the stem. This avoids needless costs, morbidity, and risk to the patient. Certain uncemented stems have extensive on-growth surfaces, and these stems are the most difficult of all stems to remove (even more so than most cemented stems). If the surgeon recognizes this preoperatively, it is best not to try to remove the stem from a proximal approach, but rather, move immediately to a vascularized door approach to remove the stem. This technique will be discussed shortly. On occasion, I will mix implants from different manufacturers, but if this is performed, it is important to know the geometry of all implants involved.

Preoperative planning is critical. In addition to knowing the implant, the surgeon should prepare for the worst case scenario, including cement removal tools, high speed cutting tools, allograft humeral onlay grafts, cables or fibroelastic bands, and plates and long stem revision implants. The health of the host is important as revision shoulder arthroplasty is a major operative procedure, which might be more than a frail patient can tolerate. Blood products including a type and cross should be available and consideration for tranexamic acid should be entertained if there are no contraindications such as renal failure, clotting disorder, or if the patient is on Warfarin.

Revision Arthroplasty Without Removing the Stem
Revision arthroplasty with retention of the stem is possible when revising a hemiarthroplasty to a total shoulder arthroplasty, a total shoulder arthroplasty to another total shoulder arthroplasty or hemiarthroplasty, and when revising a hemiarthroplasty or a total shoulder arthroplasty to a reverse total shoulder arthroplasty when a common platform stem is in place. When planning to retain the stem, it is important to ascertain whether the stem is infected by obtaining serologic markers (CBC with diff, ESR and C-reactive protein), aspiration, and intraoperative frozen sections. If there is any concern that the implant may be infected, the stem should be removed. Assuming there is no evidence of infection, the shoulder can be exposed through the original incision, which is usually deltopectoral. The humeral head is removed, and the glenoid is exposed. Glenoid exposure is facilitated by a humeral stem that does not have a male trunion fixed permanently to the stem or a removal male adapter. The surgeon then performs the reconstruction on the glenoid side followed by insertion of the modular humeral head for hemiarthroplasty or anatomic total shoulder arthroplasty (aTSA) or the tray for a reverse total shoulder arthroplasty (rTSA). These revisions are relatively quick and can be performed with little or no compromise of the proximal humerus.

Revision Arthroplasty With Stem Removal—Proximal Approach
Revision arthroplasty with stem removal varies widely with respect to the degree of difficulty. Some uncemented stems can be removed easily and others, with extensive on-growth surfaces, can be exceedingly difficult to remove. The surgeon should always plan for the worst case scenario. Another significant consideration is whether the stem is infected. If it is infected and uncemented, it may be easy to remove. However, if it is infected and well cemented distally, it will almost always require a vascularized humeral door.

Proximal extraction of the stem is preferred if possible as it is quicker and usually less destructive to the proximal humerus. A meticulous release of scar tissue and adhesions between the deltoid and the proximal humerus is performed as it will markedly facilitate exposure and minimize the chances of intraoperative fracture. All soft tissue should be removed from exposed proximal portion of the humeral implant and humeral metaphysis. A flexible osteotome should be used to disrupt the proximal bone—portions interface—or, for cemented stems, the bone-cement interface. In most cases, the stem can then be removed. Many manufacturers have a connector for the stem with a slap-hammer adapter that will facilitate stem removal. If a stem extractor is not available, a bone tamp below the anterior medial calcar of the stem directed cephalad will usually allow dissipation. Once the stem is removed, a starter reamer should be used to describe the distal pedestal. In cemented cases, all loose cement is removed, and the canal can be opened with an ultrasonic device; however, care should be taken with the extensive use of these devices. These devices generate heat and require frequent injection for cooling. Radial nerve injuries have been reported with their use even in the absence of perforations. Alternatively, if reconstruction is to be performed by cementing into the old cement mantle and the stem is too long for the cement pedestal, the stem can be shortened intraoperatively using a metal cutting tool. The ultrasonic device can be very helpful for removing the distal cement in a tapered humeral canal. It is important that the surgeon not spend excessive time attempting a proximal approach once it is clear it will not accomplish the goal of implant removal. In these situations, a vascularized door approach should be used. A vascularized door is far less destructive and safer than perforating the humerus in multiple locations while using a proximal approach.

Revision Arthroplasty With Stem Removal—The Vascularized Humeral Window/Door Approach
The vascularized humeral door approach for stem removal is reserved for the most difficult revision cases and cemented infected cases. It provides excellent exposure of the stem and intramedullary canal and, if performed correctly, is minimally destructive and relatively efficient. The window is performed by extending the deltopectoral approach into an anterolateral approach. It is very important that the brachialis not be stripped off the anterior humerus. Only a 3 mm strip of humerus directly below the anterior lateral approach is exposed (i.e., only the extreme lateral portion of the brachialis is elevated). At the conclusion of this
procedure, the brachialis will remain attached to the large anterior window. By maintaining the brachialis attachment to the door, it remains vascular and will heal rapidly. In cases of infection, it is far better to have a vascularized door than an avascular piece of bone from a window that has been completely devitalized. Using a (miter or pencil tip) small high-speed cutting tool, multiple holes are made extending from the proximal humerus to the end of the cement mantle or stem (Fig. 1). Prior to the procedure, the surgeon should determine the length of the stem or cement mantle from the medial calcar using x-ray or, alternatively, using intraoperative fluoroscopy. At the distal margin the brachialis is elevated for 3 mm from lateral to medial to where the hinge of the door is going to be constructed. The hinge of the door is constructed by using a 2.5 mm drill bit and drill guide (Fig. 2). The guide is passed through the brachialis at multiple locations starting distally and working proximally. The hinge is constructed in this manner about 10 to 15 mm medial to the previous lateral perforations and is accomplished by using the guide to perforate and protect

Figure 1 Schematic of miter-tip high-speed burr making multiple perforations along the anterior lateral cortex.

Figure 2 Schematic using a drill guide through muscle making perforations so as to create the medial hinge of the vascularized door.

Figure 3 Schematic connecting the distal medial and lateral drill holes.

Figure 4 Schematic opening the door on the medial hinge.
the muscle. The drill holes should be placed approximately 5 mm apart so the hinge can be created safely. Finally, the opening of the door is completed laterally using an oscillating saw and connecting all the lateral perforations and the distal perforation from lateral to the medial hinge (Fig. 3). Multiple large curved osteotomes are placed laterally. They are used in concert to spread out the force used to open the medial hinge. The surgeon should be patient with the opening of the door, using as many as six osteotomes placed in the lateral cortical opening (Fig. 4). The canal is now exposed, and the stem and cement can be easily removed (Fig. 5). Once the canal has been adequately debrided, a long stem implant or antibiotic spacer is placed. The door is closed using a number 2 monofilament (infection) suture placed through the lateral door and lateral cortex. In general, one proximal, one halfway distal, and one distal suture is all that is required. When these are tied, the door is effectively shut.

There are other methods of extracting a well-cemented humeral component, including windowing with complete removal of bone, episiotomy of bone and cement, or circumferential removal of bone. The vascularized door technique may be the best compromise, depending on the needs of the surgeon, because it balances concerns about bone destruction but also provides excellent access to the canal. If only partial cement removal is required, the episiotomy approach is less destructive. If complete cement removal is needed, a vascularized door would be preferred and can easily be the second stage of the episiotomy. Figure 6 shows a well-cemented fracture prosthesis that was infected. In Figure 7, the implant and all cement has been removed through a vascularized humeral door followed by insertion of an antibiotic spacer.

Reconstruction of the Humerus

Reconstruction of the humerus varies depending on the state of the remaining proximal bone. In some cases, replacing the stem with a standard stem with or without

![Figure 5](image1.png) Schematic showing full access to the intramedullary canal.

![Figure 6](image2.png) Grashey view of a well-cemented infected fracture prosthesis.

![Figure 7](image3.png) Grashey view of an antibiotic spacer in same patient after all the cement and prosthesis has been removed through a vascularized humeral door.
cement is all that is required. However, if a significant amount of metaphyseal bone is compromised or a vascularized door has been used, the defect should be bypassed with a long stem prosthesis (with or without cement). The weakened portion of the metaphysis can be reinforced with a strut onlay allograft fixed with cables or fibroelastic bands; care must be taken to be certain that all cables or bands pass deep to the radial nerve and not over the nerve. If the trap door is to be reinforced, a narrow strut can be placed laterally over the opening of the door but not over the entire door which would compromise vascularity. In the case of revision to a rTSA with absence of tuberosities, consideration should be given to use of a proximal humeral strut graft to improve stability by reconstructing the tuberosity and restoring the deltoid wrap angle.

Results and Complications

The results of humeral reconstruction have been generally good. It is rare for a complex revision to fail due to complications on the humeral side, but this can certainly occur. The most common complication with all revision surgery of this type is infection. Other complications include loosening of the implant, periprosthetic fracture, and nerve injury (radial nerve or brachial plexus).

The vascularized humeral door heals quite rapidly: usually within 8 weeks in all cases the investigator has performed (approximately 25). We have experienced one transient radial nerve palsy and one fracture distal to the window. The window has comminuted in about six cases but could be reconstructed in the same way and has not presented a problem.

Conclusions

Humeral stem removal can be difficult; however, with proper preoperative planning and a consistent surgical approach, the stem can be removed with minimal destruction of bone. The vascularized door technique for removal of well-fixed stems is efficient and effective and provides a relatively consistent reconstruction that can be expected to heal rapidly. If performed well, the removal of the humeral prosthesis and its revision should not be a reason for subsequent implant failure unless an infection occurs.

Disclosure Statement

Thomas W. Wright, M.D. is a consultant for Exactech, Inc., Gainesville, Florida, and receives royalties on products related to this article. Dr. Wright’s institution receives research support.

References