

Avoidance and Treatment of Complications in Shoulder Arthroplasty

*John W. Sperling, MD, MBA
Leesa M. Galatz, MD
*Laurence D. Higgins, MD
William N. Levine, MD
Matthew L. Ramsey, MD
John Dunn, BA

Abstract

Total shoulder replacement is well established as a treatment for a painful arthritic glenohumeral joint, typically leading to improved shoulder function and decreased pain. The frequency of revision surgery is increasing, as it is for hip and knee arthroplasty. The most common complications of shoulder arthroplasty can be avoided or successfully treated.

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Rotator cuff tears and prosthetic instability are common complications of total shoulder arthroplasty and humeral head replacement. Although these complications can occur in isolation, often they are related. The surgeon should consider whether the patient had a rotator cuff tear or instability before the surgery as well as how long after surgery the complication occurred and the impact the complication has on the patient.

Rotator Cuff Tears

A rotator cuff tear can occur before or after shoulder arthroplasty. Pre-

surgical rotator cuff pathology is common and related to the underlying diagnosis;¹ a patient with cuff tear arthropathy by definition has a rotator cuff tear. The presurgical evaluation of a patient undergoing shoulder arthroplasty should include identification of any rotator cuff tear. A rotator cuff tear was found at the time of surgery in 10.5% of patients with osteoarthritis and 27% of patients with rheumatoid arthritis; an additional 56% of patients with rheumatoid arthritis had a thinned and scarred rotator cuff.¹ The presence and extent of a rotator cuff tear can influence surgi-

cal decision making; therefore, preoperative identification of rotator cuff pathology is extremely important.

The presence of a rotator cuff tear after shoulder arthroplasty is more common than is generally appreciated. A postoperative rotator cuff tear can occur if the rotator cuff repair fails to heal, the subscapularis fails to close, or an attritional rotator cuff tear develops over time. The possible presence of a rotator cuff tear must be considered after surgery in a patient whose shoulder function either does not improve or deteriorates after a period of improvement, and a high index of suspicion for a rotator cuff tear should be maintained if the patient does not progress as expected. An early repair, particularly of a torn subscapularis, is more likely to be successful than a late reconstruction.

The symptoms of rotator cuff tearing associated with postoperative instability are so dramatic that a delay in diagnosis is uncommon. If

*John W. Sperling, MD, MBA is a consultant for or an employee of Biomet. Laurence D. Higgins, MD or the department with which he is affiliated has received royalties from Zimmer.

pain or loss of function develops in a patient with a previously well-functioning shoulder arthroplasty, the possibility of a rotator cuff abnormality should be considered. If a rotator cuff tear is suspected after the immediate postoperative period, the process of diagnosis is similar to that for a rotator cuff tear in the absence of a prosthesis. Postoperative instability associated with a rotator cuff tear usually is anterior or anterosuperior in direction. The diagnostic studies include standard orthogonal radiographs of the shoulder. Newer MRI techniques are useful in imaging the shoulder after arthroplasty.² Ultrasonography can determine rotator cuff integrity, but its usefulness depends on the skill of the technician.

The treatment of a rotator cuff tear after arthroplasty is determined based on the patient's age, activity level, and functional impairment. Many patients, particularly low-demand patients, have little functional impairment associated with a rotator cuff tear, and nonsurgical treatment is appropriate. In patients who have persistent pain, do not progress functionally, or have associated instability, the rotator cuff tear should be fixed surgically.

Postoperative subscapularis dysfunction can compromise the functional outcome of the surgery.^{3,4} An early diagnosis allows a primary repair. However, the diagnosis may be delayed because postoperative protected mobilization and guarding mask the physical findings. Some authors have promoted lesser tuberosity osteotomy as an alternative to subscapularis tenotomy.^{5,6} Displacement of the tuberosity is easily identified on routine postoperative radiographs and can be treated expeditiously. A pectoralis major transfer can be done for an irreparable sub-

scapularis tear, with or without capsular reconstruction.⁴

An anterosuperior rotator cuff tear can cause anterosuperior instability. Determining the integrity of the coracoacromial arch is critical in evaluating anterosuperior instability, as anterosuperior instability accompanied by coracoacromial arch insufficiency is not successfully treated by rotator cuff repair. Revision to a reverse total shoulder arthroplasty is typically required. An anterosuperior rotator cuff tear without fixed anterosuperior instability can be treated with a primary rotator cuff repair, a tendon transfer, or conversion to a reverse shoulder arthroplasty.

Prosthetic Instability

A review of studies published since 1980 found that instability was identified as a complication in 1.5% of patients who had undergone total shoulder arthroplasty (22 series) and 2.8% of patients who had undergone humeral head replacement (20 series).¹ Instability after arthroplasty can be defined by the direction of the instability or the underlying etiology. Although the direction of instability is obvious, the underlying causes can be subtle and must be thoroughly investigated. The factors related to the prosthesis include component malposition, size, and migration. The factors related to soft tissues include dysfunction or insufficiency of the rotator cuff and capsular laxity. Factors related to the implant and the soft tissues both commonly contribute to postoperative implant instability.

Anterosuperior instability most commonly is caused by a rotator cuff tear involving the subscapularis and supraspinatus tendons. Less frequently, anterosuperior instability develops after attritional loss of the

rotator cuff; this type of instability is most common in patients with rheumatoid arthritis. Loss of the humeral head depressor function of the rotator cuff is the most common pathomechanical factor in anterosuperior instability. If the humeral head is contained under an intact coracoacromial arch, anterosuperior instability may not lead to devastating functional limitation. However, coracoacromial arch violation during earlier surgery can lead to anterosuperior escape of the humeral head in the presence of rotator cuff deficiency.

Inferior instability generally is caused by a failure to reestablish humeral length, most commonly during reconstruction after tumor resection or humeral head replacement performed for a proximal humerus fracture. The landmarks for reestablishing humeral head height during hemiarthroplasty have not been proved. Traditionally, the height of the tuberosity fragments has been used to reestablish length. Reference measurements from the pectoralis major insertion have been proposed as a reliable indicator for appropriate reconstruction.⁷

Postoperative anterior instability most commonly is caused by humeral component anteversion, glenoid bone loss, or subscapularis disruption. Poor tissue quality, inadequate subscapularis repair, use of an oversized component, and aggressive postoperative rehabilitation have been implicated in subscapularis disruption.

Posterior instability most commonly is caused by excessive glenoid or humeral retroversion or soft-tissue imbalance (characterized by tight anterior or patulous posterior soft tissue). Excessive glenoid component retroversion occurs when the extent of posterior glenoid ero-

sion is not appreciated or corrected at surgery. Posterior instability can occur if posterior glenoid erosion is not corrected during humeral head replacement. Soft-tissue imbalance across the shoulder also has been implicated in posterior instability. Tightness in the subscapularis muscle caused by improper intrasurgical mobilization and a contracted anterior capsule can push the humeral head posteriorly.

Prosthetic instability is best avoided through careful planning and execution of the surgical procedure. Although many authors have mentioned instability as a complication of shoulder arthroplasty, few have specifically discussed the topic.⁸⁻²² Moeckel and associates¹⁸ reported that 7 of 10 patients with instability after shoulder arthroplasty had anterior instability, and 3 had posterior instability. A subscapularis rupture was diagnosed and repaired in the seven patients with anterior instability; in three of these patients, the instability was persistent and required an Achilles tendon allograft reconstruction. The posterior instability was believed to be multifactorial, resulting from soft-tissue imbalance and incorrect component version. Stability was ultimately achieved in all patients with anterior instability; one patient with posterior instability had persistent instability.¹⁸

In a review of the complications of total shoulder arthroplasty, Wirth and Rockwood²³ found anterior instability resulting from a combination of decreased humeral retroversion and subscapularis deficiency in three patients and from a combination of decreased humeral retroversion and anterior glenoid bone loss in one patient. Superior instability was attributed to dynamic muscle dysfunction, attenuation of the supraspinatus muscle, a failed rotator

cuff repair, or a rotator cuff tear. Superior migration was not always associated with pain. Posterior instability was identified in patients with unappreciated or uncorrected posterior glenoid erosion leading to glenoid retroversion. Other causes of posterior instability were excessive humeral component retroversion and nonunion of the greater tuberosity.²³ Sanchez-Sotelo and associates²⁴ identified anterior instability after shoulder replacement in 5 patients as well as anterosuperior instability in 14 and posterior instability in 14. The cause of instability was soft-tissue imbalance in 21 patients, component malposition in 1 patient, and a combination of soft-tissue imbalance and component malposition in 11 patients. Of the 33 patients, 19 had recurrent instability.

Reverse shoulder arthroplasty has recently been used as a salvage procedure after unsuccessful shoulder arthroplasty. However, reverse shoulder arthroplasty has a high rate of complications, and bimodal failure (loosening and functional deterioration) has been identified.⁴ European researchers found that reverse shoulder arthroplasty was more successful when performed for rotator cuff tear arthropathy than for revision of an unsuccessful arthroplasty. Wall and associates²⁵ reported the results of reverse shoulder arthroplasty for revision of an unsuccessful total shoulder arthroplasty in 24 patients, finding that failure of the index arthroplasty was caused by component instability, rotator cuff dysfunction, glenoid loosening, or a combination of these factors. The complication rate after reverse shoulder arthroplasty was 50%. The patients had significant improvement in pain, activity, mobility, and strength; the mean Constant score improved from 23.3 to

51.2, and functional range of motion improved from 61° to 113.5° of forward elevation. However, external rotation and internal rotation did not improve significantly. Despite the high complication rate and marginal functional improvement, 85% of the patients were satisfied with the result.

Instability and rotator cuff tears after shoulder arthroplasty are challenging to treat and are best avoided. Successful treatment requires identification of the underlying causes, and early treatment generally yields better results. Nonetheless, success often is limited. Reconstruction should be viewed as salvage surgery, offering only moderate success. Reverse shoulder arthroplasty has emerged as a salvage surgery option for patients with a rotator cuff tear or instability after shoulder arthroplasty. Although reverse shoulder arthroplasty can offer functional improvement, the complication rate is high.

Glenohumeral Loosening After Arthroplasty

Incidence

A 10% overall complication rate was reported in a compilation of 22 studies of total shoulder arthroplasty involving 1,183 procedures.²⁶ The most common of the 23 reported types of complications were rotator cuff tears (1.9%), instability (1.5%), and glenoid loosening (1.3%); humeral loosening accounted for less than 1%. Glenohumeral loosening may have been the underlying cause of more complications than its reported frequency suggests, including malposition (0.6%) and infection (0.4%)²⁶ (Figure 1). In studies of unsuccessful shoulder arthroscopy, rates of glenoid loosening as low as 9% or 13% have been reported.^{25,27} Hasan and associates²⁸

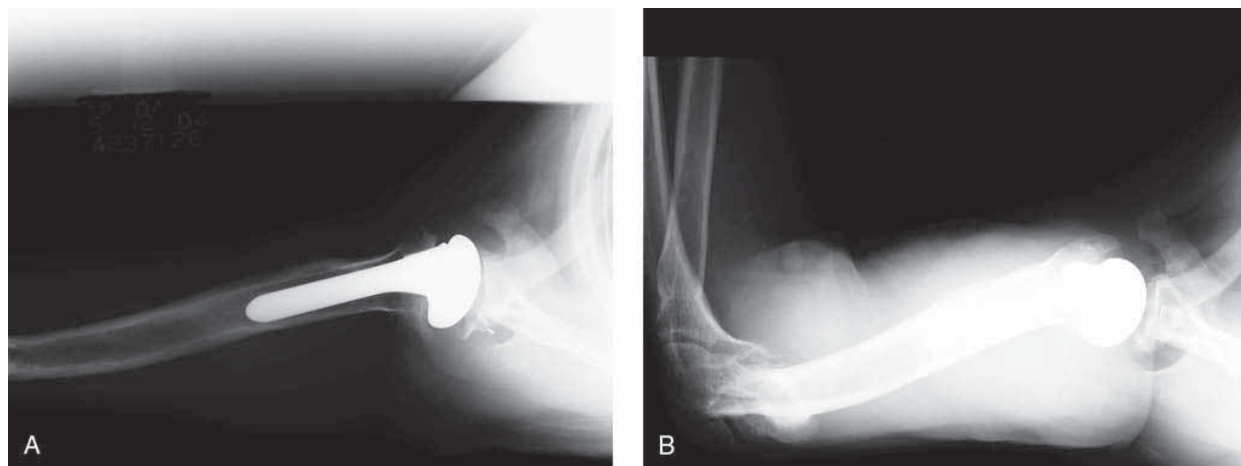


Figure 1 Radiographs of the shoulder of a 47-year-old man who had increasing pain and loss of function 2 years after total shoulder arthroplasty for instability-associated arthritis. **A**, Axillary radiograph reveals glenoid component loosening. **B**, Axillary radiograph shows revision placement of a new glenoid component.

found that as many as 59% of unsuccessful shoulder arthroplasties involved glenoid component loosening. In contrast, the rate of humeral loosening was 11%. The discrepancy is partly attributable to the method of determining loosening. Nyffeler and associates²⁹ found that CT is more reproducible than radiography for assessing the extent of loosening. A review of 20 patients with a total shoulder replacement found that glenoid lucent lines were visible on plain radiographs in 38.6% at an average 5-year follow-up.³⁰

Risk Factors

Several factors can contribute to glenoid component instability, including poor cement technique, improper prosthesis positioning, polyethylene wear, rotator cuff deficiency, and poor bone stock. Mechanically, glenoid loosening can result from cyclic eccentric loading of the humeral head on the glenoid, which is known as the rocking horse phenomenon. Torque is created at the implant-cement and bone-cement interfaces with edge or eccentric loading, resulting in compo-

nent loosening. The force from repeated eccentric loading can lead to disassociation of the glenoid component.³¹

Accurate component conformation, with a nearly identical radius of curvature, reduces glenohumeral pressure by increasing the contact area of the glenoid and humeral components. However, component conformation also increases glenoid edge loading because polyethylene does not effectively mimic the viscoelastic properties of the natural cartilage and labrum. A glenohumeral radial mismatch can help offset this effect. A mismatch of 5.5 mm to 10 mm was found to minimize the radiolucencies characteristic of loosening.³² However, a glenohumeral radial mismatch of more than 10 mm greatly increases the risk of polyethylene fracture.³³

The technique used for cement application affects the likelihood of glenoid loosening. Successful fixation of the glenoid component into the scapular neck was twice as likely if the polyethylene pegs were coated in cement and a syringe (rather than

finger pressure) was used to add cement to the peg-receiving holes.³⁴ Loosening, as revealed by radiolucency, was found to be less likely when a pegged design, rather than a keeled design, was used.³⁵

Poor glenoid bone stock, resulting from aging, disuse, or disease, can contribute to glenoid loosening. A bone graft can be internally fixed to restore peripheral glenoid bone stock and reduce the risk of loosening, although the procedure is technically difficult. However, Hill and Norris³⁶ reported that 82% of grafts healed, and the average correction was 33° of abnormal glenoid version.

Although it is less common than glenoid loosening, humeral loosening contributes significantly to the incidence of arthroplasty failure. Humeral loosening often is the direct result of improper positioning. A tight press fit is optimal to ensure centralization of the humeral stem and minimize the likelihood of humeral loosening. According to a recent study, 19% of press-fit humeral components showed evidence of

loosening at a mean 10-year follow-up.³⁷ If the fixation is compromised during primary or revision arthroplasty, filling the canal with cancellous bone and using impaction grafting are also effective in stabilizing the humeral stem.³⁸

Revision surgery is more complicated if the humeral component was cemented. The prosthesis is difficult to remove without damaging the proximal end of the humerus. A metaphyseal window can be created during the revision arthroplasty to allow direct access to the cement mantle if a revision is required. One study found no humeral loosening in patients for whom a window was created in the humeral cortex during the revision arthroplasty.³⁹

Treatment

Glenohumeral loosening can be corrected through glenoid revision surgery. Patients experience greater pain relief and a better range of motion after glenoid component reimplantation than after component removal and bone grafting. Antuna and associates⁴⁰ found that 26 of 30 patients who had reimplantation of a glenoid component after an unsuccessful total shoulder arthroscopy had significant improvement in pain, external rotation, and active elevation. Of seven patients who underwent reimplantation of the glenoid component after component removal and allogenic bone grafting, two became infected, three had an unsatisfactory Neer rating, one had a satisfactory Neer rating, and only one had an excellent postoperative rating.⁴¹

Complications of total shoulder arthroplasty are infrequent, and the risk can be decreased if an appropriate component and surgical approach are chosen and scrupulous surgical technique is used by an ex-

perienced surgeon. If loosening of the humeral component occurs, the possible causes must be specifically evaluated, including infection, malposition, and improper sizing.

Decision Making for Avoiding Glenoid Component Complications

Hemiarthroplasty often is considered for definitive treatment of osteoarthritis. In comparison with total shoulder arthroplasty, hemiarthroplasty requires less surgical time, results in less blood loss, and is less costly. Glenoid resurfacing adds to the technical difficulty of the procedure and to the potential for glenoid loosening over time. Good or excellent pain relief was reported in as many as 80% of patients with osteoarthritis after humeral head replacement alone.⁴² Although total shoulder arthroplasty and hemiarthroplasty have been considered to produce equivalent improvement in range of motion and strength, a recent systematic review found that total shoulder arthroplasty led to greater gains in forward elevation and external rotation.⁴³ Hemiarthroplasty often is considered the superior procedure for a younger, more active patient with acceptable glenoid anatomy and a balanced joint, allowing possible future conversion to a total shoulder arthroplasty. However, the outcome of hemiarthroplasty is unpredictable in these patients, and total shoulder arthroplasty results in a significantly better functional outcome.⁴⁴

Longer term follow-up has revealed that the results of hemiarthroplasty significantly deteriorate over time, suggesting that the initial conclusion that hemiarthroplasty leads to good or excellent pain relief was erroneous. In a long-term study, Cofield and associates⁴⁵ found that

only 66% of patients with osteoarthritis or rheumatoid arthritis achieved acceptable pain relief after hemiarthroplasty. Nine of 35 shoulders with osteoarthritis required revision to total shoulder arthroplasty because of unacceptable pain. Other authors also reported that patients had pain, glenoid wear, and a need for revision surgery at longer term follow-up after hemiarthroplasty.^{46,47}

Total shoulder arthroplasty is clearly superior to hemiarthroplasty for a patient with asymmetric glenoid wear and glenoid erosion.⁴⁸ Conversion of a hemiarthroplasty to a total shoulder arthroplasty has proved to be technically demanding; one study reported an unacceptable outcome in 47% of patients.⁴⁹ It is therefore imperative for the surgeon to strive for a durable, secure total shoulder replacement.

Optimizing Glenoid Fixation

Glenoid component loosening is the most dreaded complication of total shoulder arthroplasty. Reported rates of lucent lines associated with a glenoid component range from 30% to 90%, although the reported rates of symptomatic loosening requiring revision range only from 2% to 6%.⁵⁰ No definitive correlation between glenoid radiolucency and clinical outcome has been established. Refinements in glenoid preparation and cement technique as well as continuing innovations in glenoid component design have largely been motivated by concerns about glenoid failure.

Component Design

The currently preferred glenoid prosthesis designs are pegged or keeled, constructed of ultra-high molecular weight polyethylene, and cemented. Pegged components were

found to tolerate a higher pull-out load than keeled components,⁵¹ and studies of edge-loaded glenoid components found that pegged components had less displacement on their edges than keeled components.^{52,53} Although increased cement penetration into the vault was found to increase the pull-out strength of the implant, there is evidence that the use of methylmethacrylate may contribute to the development of lucencies by inducing exothermic bone necrosis immediately adjacent to the prosthesis.⁵⁴ Increasing the amount of cement generates a higher temperature. Because a pegged component requires less cement than a keeled component, less bony necrosis may occur. Several studies have found a lower incidence of postoperative glenoid lucency when a pegged component was used.^{35,55} A pegged component has the inherent advantage of requiring less bone removal than a keeled component. Because of these advantages, the use of pegged all-polyethylene components is recommended over the use of keeled components.

An all-polyethylene pegged component that achieves fixation with bony ingrowth also is a viable option. In this design, a central fluted peg promotes bony interdigitation between the flutes. Three smooth peripheral pegs are fixed with minimal cement to augment the initial stability of the component. This design theoretically leads to a durable biologic fixation. Early radiographic follow-up of 90 prostheses found bony ingrowth between the flutes in 60 prostheses (67%), although incomplete seating was noted in 38 prostheses (42%).⁵⁶

Metal-backed components were introduced in an effort to improve durability and fixation in patients with poor bone quality. Early biomechanical

investigations found improved initial fixation strength, but clinical experience revealed that the use of metal-backed components caused high, supraphysiologic stress.^{57,58} In one study of total shoulder arthroplasties, 10% of the implants were metal backed, but they accounted for 50% of the glenoid failures.⁵⁹ Implantation of a metal-backed component requires more bone removal than a polyethylene design, and extraction requires greater bony destruction. As a result, less bone is available if revision is necessary.^{59,60} The frequency of loosening after implantation of a first-generation metal-backed component was partly attributed to the substantial difference in the modulus of elasticity between metal and bone, and new types of metal-backed prostheses have been investigated.^{57,61} The ideal prosthesis should replicate the normal forces in bone, avoiding both stress shielding and excessively high stresses on the glenoid.

Porous tantalum is a metallic material with unusually high interconnecting porosity. The pores are regular in size and shape. The modulus of elasticity is quite similar to that of bone, and the 80% porosity closely resembles that of cancellous bone. Tantalum can be formed into complex shapes and used either as a bulk implant or a surface coating. Its high friction allows for a maximal initial press-fit fixation, which reduces micromotion. Subsequent ingrowth leads to an ultimate fixation several times more secure than that of the commonly used materials. This material is currently used in hip and knee arthroplasty, tumor surgery, soft-tissue reconstruction, and spinal fusion. A tantalum-backed glenoid prosthesis is under clinical investigation.

Glenoid Preparation and Cementing

The typical glenoid wear pattern in a patient with osteoarthritis is posterior erosion leading to increased retroversion. Asymmetric glenoid wear or compromised bone stock may predispose the patient to glenoid loosening. The treatment options include lowering the glenoid high side by reaming, or altering the version of the humeral component.⁶² A larger deficiency may require structural bone grafting to restore glenoid height and version; however, structural bone grafting is associated with a relatively high failure rate.

Eccentric reaming of the anterior glenoid to restore version can lead to bone stock depletion. A dual-radius glenoid component (Zimmer, Warsaw, IN) has been developed to address this difficulty by allowing a smaller glenoid prosthesis to be used with a larger diameter humeral head (for example, a 40-mm glenoid prosthesis with a 46-mm humeral head). Earlier glenoid prostheses required that the glenoid-side diameter be matched with the diameter of the humeral head, limiting the extent to which version could be compensated for by reaming. The new design allows better matching of the component to individual patient anatomy, and early reports of its use are promising.⁶³

Success in placing an all-polyethylene glenoid component depends on the cement technique. Adequate exposure and meticulous preparation are required.⁵⁵ After reaming and drilling, pulsed lavage is used to remove any blood and debris from the vault, which is packed with thrombin-soaked sponges to dry the prepared bone. Three applications of cement are followed by serial compression to increase cement penetration into the bony interstices (G Marra, MD, Chicago,

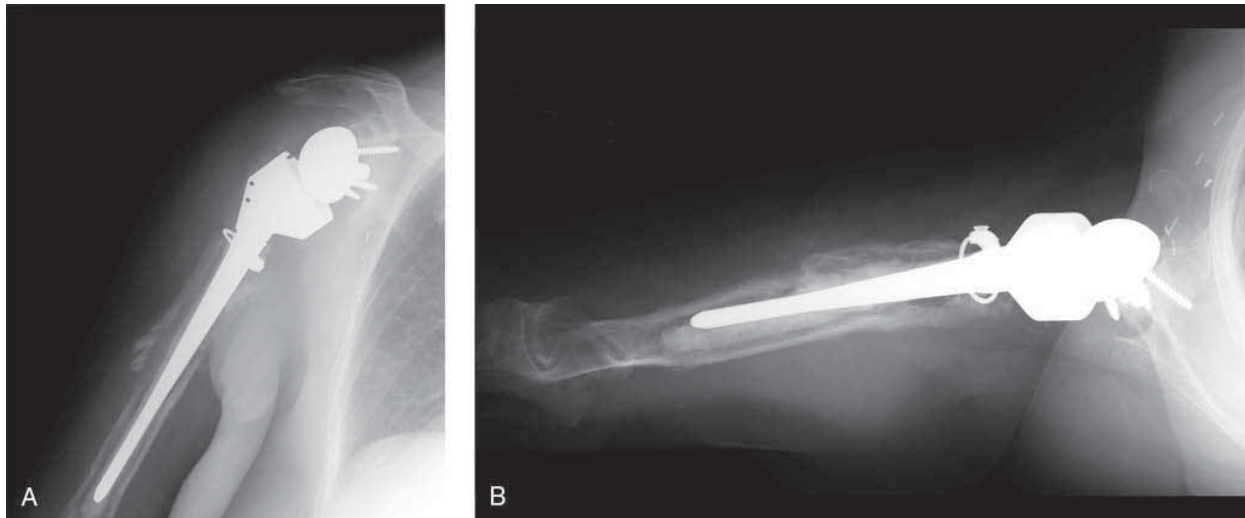


Figure 2 AP (A) and axillary (B) radiographs of the shoulder of a 60-year-old woman with an infected long-stem reverse prosthesis. Significant periprosthetic lucency and periosteal new bone formation are present.

IL, unpublished data, 2007). Cement placement must be restricted to the vault, avoiding the surface. Applying excessive cement to the glenoid face can lead to early failure because the component will rely on the cement rather than the bone for support. Reaming to a smooth osseous surface can ensure that the bone will fully support the glenoid component.

Careful decision making is critical to the outcome of shoulder arthroplasty. In general, total shoulder arthroplasty is recommended if the glenoid is affected by osteoarthritis, rheumatoid arthritis, or advanced osteonecrosis with glenoid involvement. To enhance glenoid prosthesis stability, the use of eccentric reaming, a modern cementing technique, and, occasionally, a mismatched glenoid design are recommended. Future advances in metal-backed component design, including the use of tantalum, may further improve durability and patient outcome. Although there is great concern about

radiolucency after glenoid implantation, all-polyethylene glenoid implants have a low clinical failure rate; failure of hemiarthroplasty, requiring conversion to total shoulder arthroplasty, is more common.⁴³

Infection After Shoulder Arthroplasty

Infection is a rare but devastating complication of shoulder arthroplasty (Figure 2). The reported frequency of infection after an unconstrained primary shoulder arthroplasty ranges from 0% to 4%.^{64,65} Diagnosing an infection can be difficult, especially among patients undergoing revision arthroplasty. Most of these patients do not have overt signs of infection, such as erythema or sinus tracts. A detailed patient history is important in determining the duration of the infection as well as its classification.

Topolski and associates⁶⁶ reviewed preoperative and intraoperative studies of 75 patients who had no overt signs of infection before

revision shoulder arthroplasty but had positive intraoperative cultures. The preoperative findings were as follows: white blood cell count, negative in 67 of 72 patients (93%); polymorphonuclear cell percentage distribution, negative in 64 of 70 patients (91%); erythrocyte sedimentation rate, negative in 36 of 42 patients (86%); and C-reactive protein level, negative in 12 of 16 patients (75%). The intraoperative histologic report was negative in 67 of 73 patients (92%). The most common of the cultured bacteria was *Propionibacterium acnes* (in 45 of 75 patients [60%]). The authors noted that none of the available preoperative or intraoperative studies can reliably predict whether a patient will have a positive intraoperative culture.

The goals of treatment are to eradicate the infection, improve pain, and maximize shoulder function. The options for an infected shoulder arthroplasty include débridement, antibiotic suppression,

resection arthroplasty, and one- or two-stage reimplantation.

Débridement

Débridement with retention of the components appears to be best suited for a patient with either an early infection or an acute infection and a well-functioning prosthesis. A susceptible organism, well-fixed components, and an absence of sinus tracts are preferred. Intravenous antibiotics usually are prescribed after débridement, often followed by a course of oral antibiotics. A comprehensive review of knee arthroplasty studies found that débridement led to a successful outcome in 140 of 445 knees with an infection.⁶⁷

Coste and associates⁶⁵ reported on the outcome of 49 periprosthetic shoulder infections, finding that débridement alone was ineffective. The authors noted a “tendency to misdiagnose chronic infection or, if the diagnosis was made, to delay before reoperating.” Sperling and associates⁶⁴ reported that three of six shoulders became reinfected after débridement with retention of the prosthesis, eventually requiring resection arthroplasty.

Antibiotic Suppression

Only limited research is available on long-term antibiotic suppression for the treatment of an infected shoulder arthroplasty, but antibiotic suppression for an infected knee arthroplasty has had poor results. Hanssen and Rand⁶⁷ reviewed the literature on antibiotic treatment of an infected total knee arthroplasty and found that it was successful in only 24% of patients. The patients most appropriate for treatment with antibiotic suppression probably are those who have a low-virulence organism, well-fixed components, and a medical comorbidity that unacceptably increases the risks of surgery.

Resection Arthroplasty and Arthrodesis

Resection arthroplasty was more frequently used in the past for the treatment of an infected shoulder arthroplasty. Rispoli and associates⁶⁸ reviewed the outcome of shoulder resection arthroplasty in 18 patients, 13 of whom had an infection. Pain significantly improved ($P < 0.001$), and mean elevation improved to 70°. Resection arthroplasty may be suitable for a patient with significant soft-tissue and bone deficiency as well as a significant medical condition.

Implant resection followed by arthrodesis can be considered for a patient with an infected shoulder arthroplasty. However, significant deficiencies of glenoid and humeral bone stock typically are present after component removal, possibly resulting in shortening of the arm. In addition, the remaining surface area may be too small for fusion. Fusion can be considered for a young, active patient with high functional demands as well as a patient with rotator cuff and deltoid deficiency. Arthrodesis can be performed in one or two stages, depending on the severity of the infection. Several fusion techniques have been described, including external and plate fixation.⁶⁹

Reimplantation

A one-stage reimplantation of an infected shoulder arthroplasty typically involves component removal, thorough débridement, and placement of new components secured by antibiotic-impregnated cement. Intravenous antibiotics typically are used during the postoperative period, with modification of the regimen based on the susceptibility of the organism. Ince and associates⁷⁰ reported that nine patients treated for a periprosthetic infection with a

one-stage exchange had a mean Constant score of 33.6 at a mean 6-year follow-up. None of the patients had a recurrence of infection.

Two-stage reimplantation is the most widely accepted treatment of an infected shoulder arthroplasty. The components are removed, and a methodical débridement is performed. If the humeral component was well fixed, a humeral window or longitudinal split in the cortex may be necessary to complete the cement removal.³⁹ An antibiotic cement spacer is frequently placed, followed by treatment with intravenous antibiotics for 4 to 6 weeks.⁷¹ Reimplantation is typically performed 6 to 8 weeks after component removal.

Jerosch and Schneppenheim⁷² reported that 10 patients treated with two-stage reimplantation had a mean Constant score of 48 at the last follow-up (range, 6 to 30 months), and none of the patients had a reinfection. Component resection and placement of an articulating cement spacer was performed, and the patients received physical therapy while the cement spacer was in place.

Periprosthetic Fracture

Periprosthetic humeral fracture is an uncommon but potentially devastating complication of shoulder arthroplasty (Figure 3). The incidence of these fractures is reported to range from 0.5% to 3%, and they account for approximately 20% of complications after shoulder arthroplasty. Most such fractures occur during surgery and can be attributed to surgical technique.^{23,73,74} Postoperative humeral fractures typically occur as the result of a fall or other trauma.⁷⁵

Etiology and Risk Factors

Poor bone quality is a consistent risk factor for periprosthetic fracture.

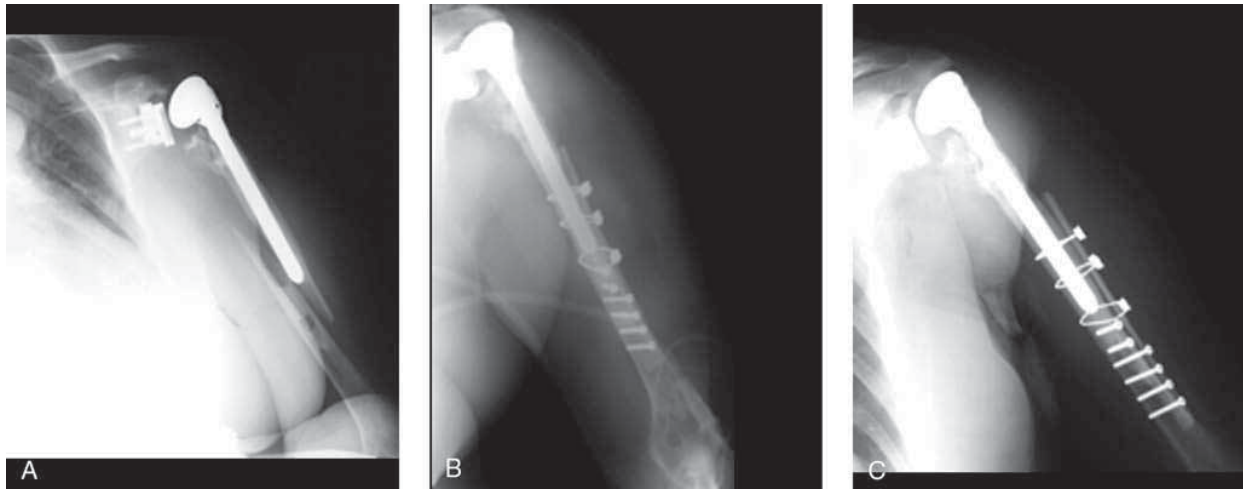


Figure 3 A, AP radiograph showing a type A periprosthetic fracture and a well-fixed humeral component. The fracture extends through the bone and cement mantle. (Reprinted with permission from Kumar S, Sperling JW, Haidukewych GH, Cofield RH: Periprosthetic humeral fractures after shoulder arthroplasty. *J Bone Joint Surg Am* 2004;86:680-689.) B, AP radiograph showing fracture fixation using a cortical allograft, screws, and cables. C, AP radiograph showing fracture healing 4 months after surgery. The cortical strut has not incorporated into the repair.

Campbell and associates⁷⁶ described a technique for grading bone quality on humeral radiographs. Osteopenia is graded using the ratio of the width of the mid-diaphyseal cortices to the diameter of the diaphysis. The normal ratio is above 50%; 25% to 50% is considered mildly osteopenic, and a ratio below 25% indicates osteopenia. Of 21 fractures, 45% were in mildly osteopenic bone, and 30% were in severely osteopenic bone. Kumar and associates⁷⁷ reported that 9 of 16 periprosthetic fractures were mildly osteopenic and 7 were severely osteopenic.

Periprosthetic fractures are more common in women and in patients with rheumatoid arthritis. In several studies, 33 of 38, 7 of 9, 7 of 7, and 5 of 6 patients were found to be women.⁷⁸⁻⁸¹ However, a study of 20 patients reported an even distribution between women and men.⁷⁶ Five of nine patients with a fracture had rheumatoid arthritis in one study,⁷⁵ and five of seven had rheumatoid arthritis in another study.⁸²

This trend was not apparent in other studies; only 17 of 64 patients with a periprosthetic fracture had rheumatoid arthritis in three combined studies.^{76,82,83}

Surgical technique is important in the etiology of periprosthetic fractures of the humerus. Lee and associates⁷⁹ simulated the effect of reaming the humeral canal for a press-fit prosthesis. Unlike the humerus, the reamer is a perfect cylinder, and preferential reaming and thinning of the anterior and posterior cortices of the humerus were found to occur during the procedure. The authors suggest that reaming can weaken the cortical bone and increase the risk of fracture. Choo and associates⁸⁰ used strain gauges along the humeral shaft of cadaver specimens to study the effect of reaming the humeral canal and placing a humeral implant. The average strain on the humeral shaft was found to increase by 30% during reaming and sometimes increased as much as 49% above the

baseline. Prosthesis implantation was found to increase the shear strain. Plausinis and associates⁸¹ used three-dimensional finite element analysis to study the effect of placing ipsilateral shoulder and elbow prostheses and found that stress concentration was not affected by the size of the bone bridge or the use of cement to fill the space. The conclusion was that an implant can be safely used without increasing the risk of periprosthetic fracture.

Campbell and associates⁷⁶ closely examined 21 periprosthetic fractures to determine the mechanism of fracture. Five fractures were intentionally created to facilitate removal of a well-fixed stem during revision surgery. Eight fractures were attributed to excessive external rotation; the surgical exposure was difficult in most of these patients because of scarring or large musculature. An oversized broach or prosthesis caused three transverse or oblique fractures. The remaining five fractures resulted from a postoperative fall. The authors con-

cluded that most of the fractures could have been prevented by better surgical technique.

Classification

Four schemes are currently accepted for classifying periprosthetic humeral fractures. Groh and associates⁸⁴ described three types: type I is proximal to the stem tip; type II has a fracture line extending from a point proximal to the stem tip to a point distal to the stem tip; and type III is distal to the stem tip. Campbell and associates⁷⁶ described four types based on the most distal extent of the fracture: type I involves the tuberosities, type II involves the metaphysis, type III involves the proximal diaphysis, and type IV extends to the middle and distal humeral diaphysis. Worland and associates⁸³ based their system on both fracture location (type A, around the tuberosities; type B, around the stem; type C, distal to the stem) and implant stability (type B1, a spiral fracture with a stable stem; type B2, a short oblique or transverse fracture with an unstable stem; and type B3, any fracture with an unstable stem). The most commonly used system is that of Wright and Cofield,⁷⁵ which is based on the location of the fracture in relationship to the stem tip. A type A fracture is centered at the stem tip and extends proximally more than one third of the stem length, a type B fracture occurs at the stem tip but does not extend proximally, and a type C fracture is distal to the stem tip.

Intrasurgical Fracture Treatment

Most periprosthetic fractures occur during surgery. There is general agreement that these fractures should immediately be treated with stable fixation to ensure the fracture will not interfere with the patient's

postoperative rehabilitation and lead to a poor result. Bonutti and Hawkins⁸⁵ reported that three intrasurgical humeral fractures failed to heal after nonsurgical treatment. However, some stable, nondisplaced fractures of the tuberosities can be treated nonsurgically. A displaced fracture of the tuberosities should be fixed with heavy suture or wire.⁷³

The treatment of a fracture of the metaphysis is based on stem stability. A stable stem can be left in place, and the bone of the stem can be fixed with cerclage wire, with or without bone grafting. An unstable stem should be removed, and the fracture should be bypassed by two to three cortical diameters. Campbell and associates⁷⁶ treated six fractures with a stable stem and either tuberosity or metaphyseal involvement. Cerclage wire was used for five fractures. All six fractures healed, with an average time to union of 2.7 months.

An intrasurgical fracture occurring at or near the stem tip usually is treated by bypassing the fracture by two to three cortical diameters and adding proximal fixation as necessary. Campbell and associates⁷⁶ treated five distal fractures using this method. The average time to union was 1.8 months, and none of the patients had delayed rehabilitation.

Postoperative Fracture Treatment

The treatment of a postoperative fracture is relatively complex. The patient's general health and functional demands must be considered before proceeding with surgery. Kim and associates⁸⁶ reported that two postoperative fractures in frail, elderly patients were successfully treated with a fracture brace. These fractures had occurred around the stem tip, and they were widely dis-

placed and angulated. They healed after approximately 3 months. The patients were pain free and had a functional range of motion despite the malunion. Campbell and associates⁷⁶ described five postoperative fractures with a stable stem and acceptable alignment, four of which were distal to the stem. The patients were treated successfully with a cast or brace and healed after an average 3.5 months. Kumar and associates⁷⁷ reported that three of four Wright and Cofield type A fractures and two type C fractures healed without surgical treatment. This study supports the nonsurgical treatment of a minimally displaced type A fracture and a type C fracture with acceptable alignment or mitigating patient factors.

A fracture with an unstable stem, a displaced tuberosity fracture, a fracture around the tip of the prosthesis, or a displaced fracture distal to the tip should be treated surgically. A fracture with an unstable stem should be treated using a long-stem implant that bypasses the fracture site by two to three cortical diameters. Proximal fixation using cerclage wires or another method usually has a satisfactory result.^{73,83} Nonsurgical treatment can be tried for a stable fracture around the tip of the stem, although nonunion often results. Kumar and associates⁷⁷ reported that four of five fractures that were deemed stable around the prosthesis tip progressed to nonunion and subsequently required surgery to achieve union. Boyd and associates⁷⁸ found six nonunions in seven nonsurgically treated type B fractures.

An unstable fracture with a stable stem should be treated surgically, if the patient is able to withstand surgery. A stable prosthesis does not need to be removed, and the frac-

ture should be treated with open reduction and internal fixation.^{75,76,78}

Kent and associates⁸⁷ described treatment of a type B fracture with a stable stem 3 years after hemiarthroplasty. A locking compression plate and proximal cerclage wires were used, and radiographic union was achieved after 8 weeks.

Periprosthetic humeral fracture after shoulder arthroplasty is relatively rare, occurring in 0.5% to 3% of patients. It has been proved that good surgical technique can prevent most of these fractures. An intraoperative fracture should receive both a stable implant and rigid fixation to ensure fracture union and the patient's ability to actively participate in postoperative therapy. Most postoperative fractures can be successfully treated without further surgery, if the stem and fracture are both stable. However, fractures around the tip of the stem tend to lead to nonunion. An unstable fracture with a stable stem should be treated with open reduction and internal fixation, and a fracture with an unstable stem should be bypassed by revision with a long-stemmed implant.

Summary

Careful preoperative planning is an essential component in minimizing complications associated with shoulder arthroplasty. In addition, an understanding of the most frequent complications associated with shoulder replacement will facilitate the rapid detection of injury and appropriate management of the patient.

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