Review Article

Periprosthetic Postoperative Humeral Fractures After Shoulder Arthroplasty

Joaquin Sanchez-Sotelo, MD, PhD

George S. Athwal, MD

ABSTRACT

The increased utilization of shoulder arthroplasty, including revision procedures, combined with rises in life expectancy, is expected to translate into a substantial increase in periprosthetic humeral fractures. The evaluation and management of these fractures needs to be updated to consider fractures that complicate anatomic and reverse arthroplasties and contemporary short-stem and stemless implants. Although conservative treatment is successful in a large proportion of these fractures, several surgical reconstructive techniques are required for the management of all fracture types. Surgical options include internal fixation, graft augmentation, standard revision procedures, and occasionally complex reconstructions including modular segmental prosthesis and allograft prosthetic composites. Most studies on the outcomes of periprosthetic humeral fractures have analyzed small samples and have typically reported on anatomic total shoulders with a standard-length humeral implant. Additional research is required to optimize the management of periprosthetic postoperative humeral fractures in the era of reverse arthroplasty, short stems, and stemless arthroplasty.

From the Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, (Sanchez-Sotelo), and the Roth/McFarlane Hand and Upper Limb Centre, London, Ontario, Canada (Athwal).

Correspondence to Dr. Sanchez-Sotelo: Sanchezsotelo.joaquin@mayo.edu

Sanchez-Sotelo or an immediate family member has received royalties from Stryker; serves as an consultant to Stryker, Acumed, Exactech; has stock or stock options held in PrecisionOS, PSI; honorarium from JSES. Athwal or an immediate family member has received royalties from Stryker; Exactech, and ConMed; serves as an consultant to Stryker; has stock or stock options held in PrecisionOS, PSI, Reach Orthopedics; honorarium from JSES.

J Am Acad Orthop Surg 2022;00:1-13

DOI: 10.5435/JAAOS-D-21-01001

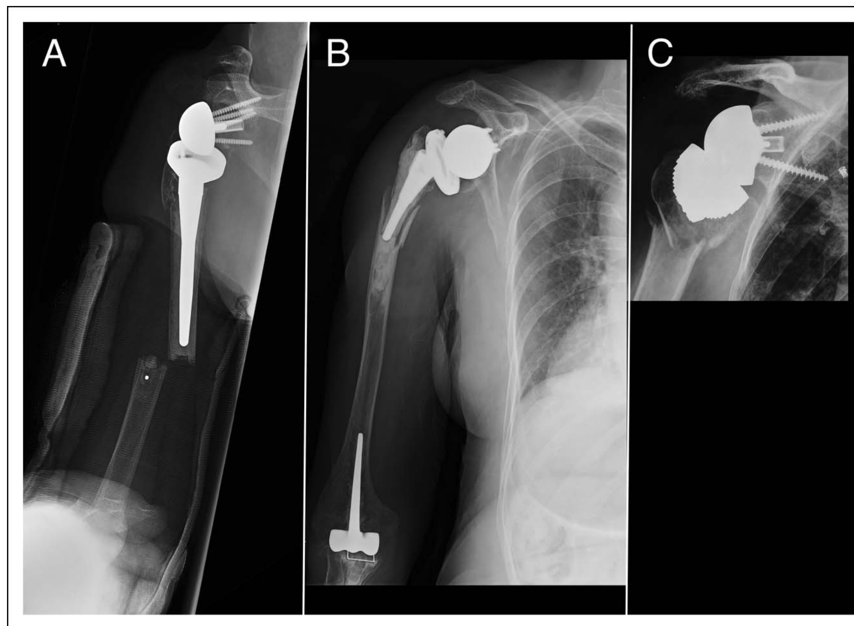
Copyright 2022 by the American Academy of Orthopaedic Surgeons.

Shoulder arthroplasty is being done with an increased frequency. More shoulder arthroplasty procedures are being conducted in younger patients, but also in the very elderly. If we consider continued increases in life expectancy as well, it is easy to understand that the number of living individuals with one or both shoulders replaced will become quite substantial.[1] All those shoulders are potentially subject to complications. Therefore, periprosthetic humeral fractures are expected to become more common, and they may certainly present a substantial dilemma, especially for older patients who need gait aids or use their upper extremities to transfer.

Most published studies on periprosthetic fractures report case series of anatomic total shoulder arthroplasties conducted with standard-length stems.[2-8] Unfortunately, there is relatively little literature on the management and outcomes of periprosthetic fractures after reverse shoulder arthroplasty (RSA). In addition, shorter stems have been introduced with the purported advantages of easy revisability and less stress shielding.[9] Finally,

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 1



Radiographs showing periprosthetic humeral fractures around a standard-length stem (**A**), a short stem (**B**) and a stemless prosthesis (**C**). Principles of management for periprosthetic humeral fractures need to consider the stem length and style, whether the arthroplasty is anatomic or reverse, fracture pattern, bone stock, and other factors, such as the possibility of an ipsilateral elbow arthroplasty.

newer stemless implants have also been designed to minimize diaphyseal instrumentation and preserve the bone. The implications of humeral implant design (anatomic or reverse; or standard-length, short-stem, or stemless implant) on the management of periprosthetic humeral fractures have not been explored in detail (Figure 1).

Epidemiology

Incidence

The rate of periprosthetic postoperative humeral fractures after shoulder arthroplasty is difficult to estimate accurately. This is partly because of (1) the wide range of follow-up lengths in studies on the topic, (2) some fractures around loose implants being reported as loosening as opposed to fracture, and (3) the tendency to not report on complications treated nonsurgically, which is relevant to the management of periprosthetic humeral fractures because many are treated nonsurgically.

One registry-based study from the Mayo Clinic reported a 0.9% rate of postoperative periprosthetic humeral fractures in 4,019 shoulder arthroplasties implanted between 1976 and 2008.[3] However, the study did not capture a representative rate of fracture after RSA because RSA only became available in the United States in 2004, and initial utilization was cautiously slow. Another study from the same institution estimated the 20-year cumulative risk of revision surgery for a periprosthetic fracture after anatomic total shoulder arthroplasty to be 2.6% (95% confidence interval, 0.8% to 4.4%). In a study on the epidemiology and future projections of periprosthetic fractures, Della Rocca et al reported rates ranging between 0.5% and 3%[10] and other authors reported similar rates (0.5%,[11] 1.9%,[12] and 2.6%[13]). Atoun et al,[14] however, reported a much higher rate of 16% after implantation of a modern short metaphyseal stemmed RSA. All five fractures in the case series of Atoun occurred after a traumatic fall.

A contemporary study is needed to determine how the overall incidence and burden of postoperative periprosthetic humeral fractures after arthroplasty is being influenced by important factors, such as the increased overall utilization of shoulder arthroplasty, increased utilization of RSA in particular, growing population and age of shoulder arthroplasty patients, surge of revision shoulder arthroplasty, and new designs of implants (stemless and short stem).

Risk Factors

Cited risk factors for *postoperative* periprosthetic humeral fractures include a higher Charlson Comorbidity Index (odds ratio, 1.27, with a 95% confidence interval

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

between 1.1 and 1.4)[3]; osteopenia[4,7]; and humeral bone loss secondary to aggressive reaming at the time of surgery, loosening, and/or osteolysis.[4] Female sex, older age, conditions that increase the risk of falling, adverse bone remodeling secondary to stress shielding, presence of an ipsilateral total elbow arthroplasty, and revision procedures may also carry an increased risk, but the statistical significance of these factors remains unproven or has not been investigated in detail.

Classification Schemes

Commonly used classification systems for periprosthetic humeral fractures after shoulder arthroplasty were developed before the introduction and widespread implantation of reverse arthroplasty, short stems, and stemless humeral implants.

Wright and Cofield[8] classified fractures into A (fracture centered at the tip of a standard-length stem and extending proximally more than one-third of the stem length), B (fracture centered at the tip with less proximal extension), and C (fracture extending distal to the stem). Andersen et al reported low interobserver reliability for this classification.[11] Campbell et al classified humeral periprosthetic fractures based on location, including the tuberosities, metaphysis, proximal diaphysis, and middle-to-distal diaphysis.[7] Worland et al defined type A as tuberosity fractures, type B as those around the stem, and type C as those distal to the stem[5]; type B was subclassified into spiral with a stable implant (B1), transverse or short oblique with a stable implant (B2), and associated with implant loosening (B3). Groh et al classified fractures as I (proximal to the tip of the prosthesis), II (proximal to the tip of the prosthesis but also extending distal to it), and III (entirely distal to the tip of the prosthesis).[15]

As humeral implant options in primary and revision arthroplasty have evolved, so must the classification systems and management techniques to address fractures complicating stemless, short, standard, and revision prostheses. To address this expanded need, Kirchhoff et al[16] published a new classification system that considers the type of prosthesis, condition of the cuff, location and pattern of the fracture, and status of the stem (loose or well-fixed).

Managing multiple cases of postoperative periprosthetic humeral fractures treated at our institutions has prompted us to expand on the Unified Classification System.[17] Presently, we classify postoperative periprosthetic humeral fractures into the following three categories: fractures of the tuberosities (type I), diaphyseal fractures overlapping the humeral implant (type II), and fractures completely distal to the humeral implant (type III). However, our observations have included several novel factors related to the fracture location in reference to the stem style (standard, short, or stemless) and the bone stock available proximally and distally (Table 1).

Type I (Tuberosity) Fractures

Most periprosthetic postoperative tuberosity fractures involve the greater tuberosity, although fractures of the lesser tuberosity are included in this category for completeness. When a greater tuberosity fracture occurs in the setting of a standard-length stem, it would be rare for the fracture to be associated with humeral loosening; however, if the fracture is displaced, function of the rotator cuff may be compromised. In contrast to a standard-length stem, a greater tuberosity fracture in a short-stem or stemless implant might compromise the stability of the implant (Figure 2). The clinical importance of a greater tuberosity fracture may also be very different when it occurs after anatomic or reverse arthroplasty because reverse arthroplasty is less dependent on an intact rotator cuff attachment.

Type II (Peri-implant) Fractures

These fractures involve the diaphysis and overlap with the humeral implant (or at a minimum with the cement column and cement restrictor when they occur in shoulders with a cemented humeral implant). There are three subcategories of type II fractures.

Type IIA—Well-fixed Humeral Implant

Important factors to consider in type IIA fractures are the type of humeral implant (standard, short, or stemless), orientation of the fracture line, and available bone proximal to the fracture line for acceptable fixation (Figure 3). Overall, *transverse* fractures seem to be more unstable with a higher rate of nonunion than *oblique* fractures. In addition, transverse fractures through the bone and cement mantle are worrisome because the fractured cement column may interfere with fracture healing.

Type IIB—Loose Humeral Implant With Adequate Bone Stock

The fracture plane may also be oblique or transverse, but this may be less relevant regarding decision making between conservative and surgical management because humeral loosening would be considered by most as an indication for revision of the humeral implant and surgical management of the associated fracture (Figure 4).

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Table 1. **Modified Unified Classification of Postoperative Periprosthetic Humeral Fractures After Shoulder Arthroplasty**

<table>
<tr><td rowspan="3">I</td><td rowspan="3">Tuberosities</td><td rowspan="3">I—GT Greater tuberosity
I—LT Lesser tuberosity</td><td colspan="2">Standard-length stem</td></tr>
<tr><td rowspan="2">Short stem or stemless</td><td>IA—Well-fixed humeral implant</td></tr>
<tr><td>IB—Loose humeral implant</td></tr>
<tr><td rowspan="5">II</td><td rowspan="5">Peri-implant</td><td>IIA—Well-fixed humeral implant</td><td rowspan="2">Transverse (IIBt) vs oblique (IIBo)</td><td rowspan="2">Standard length, short stem, stemless</td></tr>
<tr><td>IIB—Loose humeral implant with adequate bone stock</td></tr>
<tr><td rowspan="3">IIC—Loose humeral implant with inadequate bone stock</td><td colspan="2">IIC1—Severe proximal bone loss</td></tr>
<tr><td colspan="2">IIC2—Inadequate distal bone stock (failed long stem, ipsilateral elbow arthroplasty)</td></tr>
<tr><td colspan="2">IIC3—Combined proximal and distal lack of sufficient bone stock</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Distal</td><td colspan="3">IIIA—Adequate proximal bone stock</td></tr>
<tr><td>IIIB—Inadequate proximal bone stock</td><td colspan="2">Short stem or stemless + very high type III fracture</td></tr>
</table>

However, in type IIB (in contrast to type IIC), revision may be successfully done without complex reconstructive procedures such as allograft prosthetic composites or segmental humeral arthroplasty prostheses. Nonsurgical management may be considered; however, healing of the fracture with subtle malalignment may make eventual revision procedures difficult if a longer stem is needed because negotiating a longer straight stem past healed diaphyseal malalignment can be challenging.

Figure 2

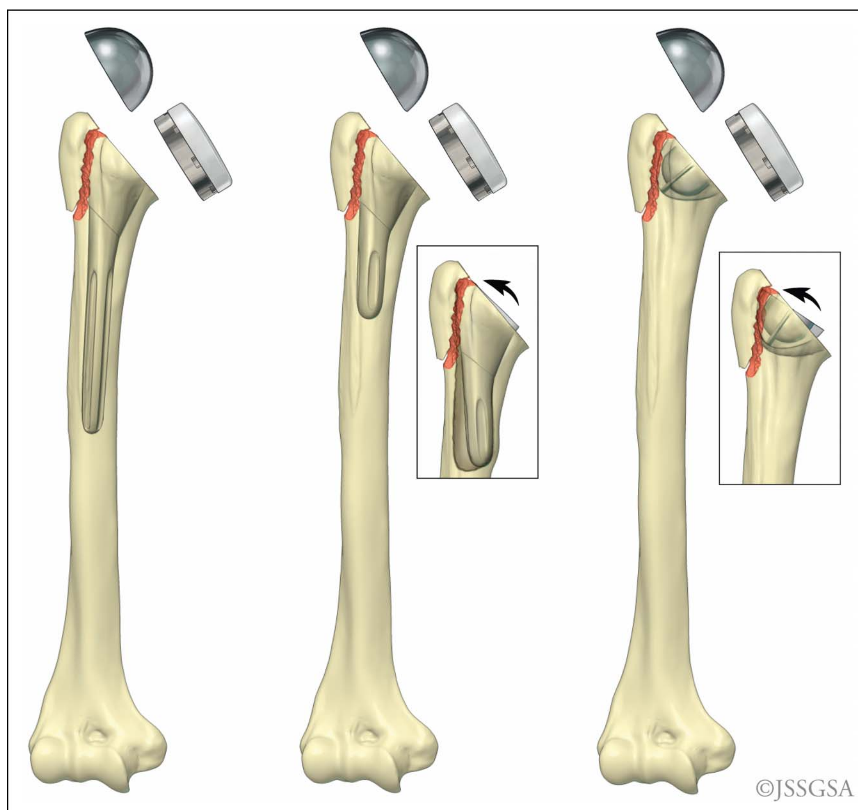


Illustration showing type I fractures.

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 3

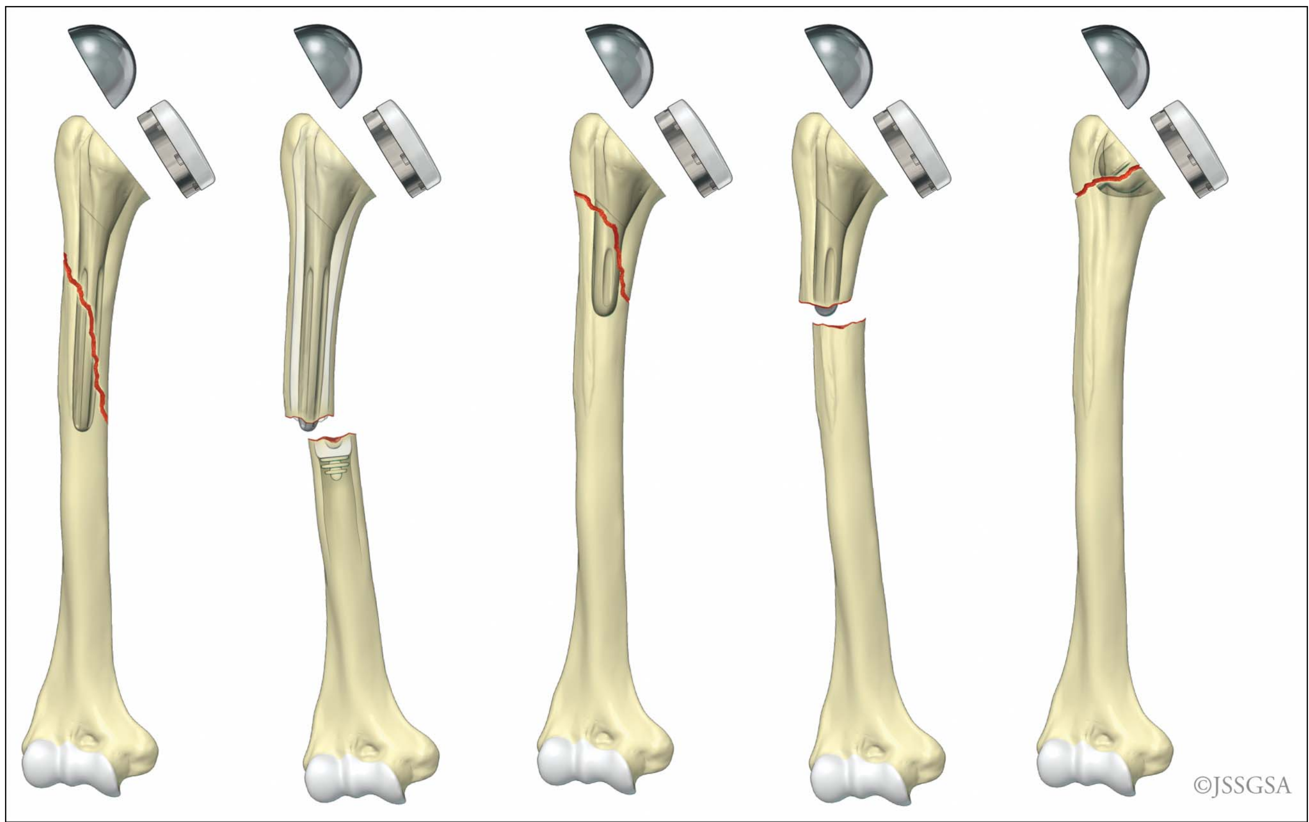


Illustration showing type IIA fractures.

Type IIC—Loose Humeral Implant and Severe Bone Loss

The hallmark of this fracture class is the severe bone loss, which generally precludes fixation and requires complex reconstruction techniques, such as allograft prosthetic composites or modular segmental prostheses. In addition, the complexity may be increased when the remaining distal bone stock is compromised by the length of loose long-stem revision humeral implants or by the presence of an ipsilateral elbow arthroplasty (Figure 5). As such, the inadequate bone stock is usually proximal; however, it could be distal or combined. In such cases of pan-humeral insufficiency, staged procedures may be required for bone reconstitution or possibly total humeral arthroplasty.

Type III (Distal) Fractures

These fractures are clearly distal to and do not overlap with the humeral implant or the cement mantle (Figure 6): The most proximal aspect of the fracture line does not overlap with the humeral implant or any cement or cement restrictor. Theoretically, the indications for surgical or nonsurgical management for these fractures can follow the general principles of non-periprosthetic humeral shaft fracture treatment. When these fractures are well below a stemless or short-stemmed implant, the implant will not likely have an influence on the fracture management or fixation technique. However, as the fracture line becomes more proximal, the proximity of a stem will likely influence the fixation technique when surgery is considered necessary. Overall, it may be best to proximally overlap the fracture fixation device with the distal aspect of the stem to avoid stress-risers. Fixation of these fractures can become more challenging with a proximal fracture line just distal to a short-stem metaphyseal filling implant. In these cases, obtaining robust proximal fixation is challenging because the proximal humeral metaphyseal area is occupied by a thicker metaphyseal filling short-stem implant.

Patient Evaluation

History and Physical Examination

A complete history is required to determine the mechanism of fracture, antecedent symptoms/joint function, and associated medical comorbidities, as well as a careful assessment of gait balance and other risk factors for falls.

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 4

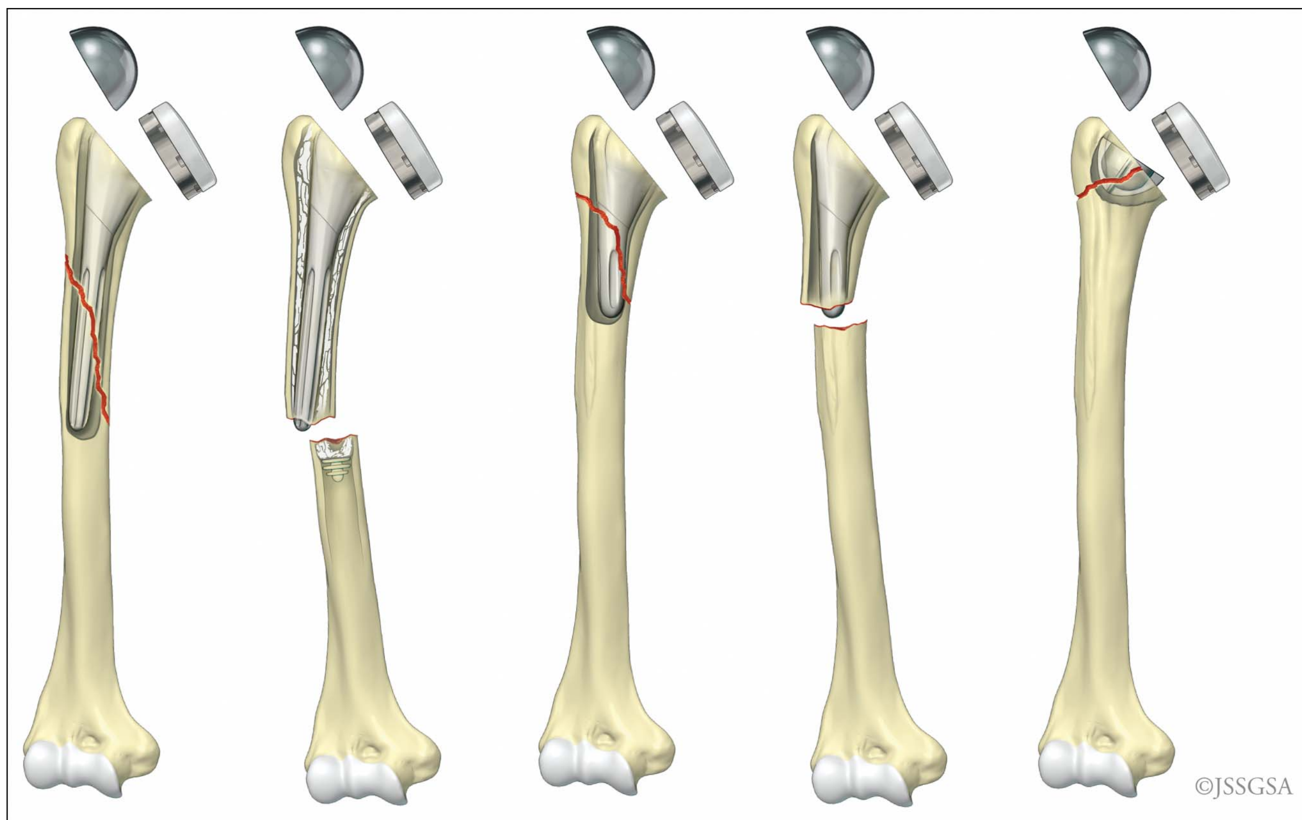


Illustration showing type IIB fractures.

The evaluation of patients after fracture is similar to the workup of other complications after shoulder arthroplasty. Table 2 outlines certain aspects of the history and physical examination that are important in patients presenting with a postoperative periprosthetic humeral fracture. Details should be collected regarding the indication for the index shoulder arthroplasty (including underlying diagnosis and components implanted); other complications or revision surgeries that may have happened in the past; and the overall pain, function, and satisfaction before the fracture occurred. A review of the overall patient health is necessary to identify modifiable and nonmodifiable risk factors predictive of poor bone healing and perioperative complications. The use of gait aids and need for transfers using the upper extremities should be specifically assessed, especially for older patients.

Comprehensive assessment of shoulder motion and strength is impractical in the presence of a fracture, but the patient may be able to demonstrate with the opposite extremity the approximate range of motion that the affected shoulder provided before the fracture. For patients with a displaced fracture of the greater tuberosity, the new presence of an external rotation lag sign may be indicative of cuff deficiency secondary to the fracture. A detailed examination of the deltoid and axillary nerve is important. Previous operations may have compromised the deltoid, such as anterior deltoid dehiscence secondary to a prior open rotator cuff repair. Distal neurovascular examination should be completed and carefully documented, especially regarding the radial and musculocutaneous nerves.

Imaging and Other Studies

Radiographs of the affected shoulder and full-length ipsilateral humerus should be scrutinized to understand the fracture pattern and to assess implant fixation, bone quality, presence or absence of cement, and other findings that may affect fixation strategies (prior humerus or elbow plating, deformity, an ipsilateral elbow arthroplasty, and others). Comparative analysis of sequential radiographs obtained over time may be particularly relevant to identify glenoid or humeral implant loosening when recent radiographs are nondiagnostic. Radiographs of both humeri with magnifier markers are helpful in fractures with severe bone loss (type IIC) to

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 5

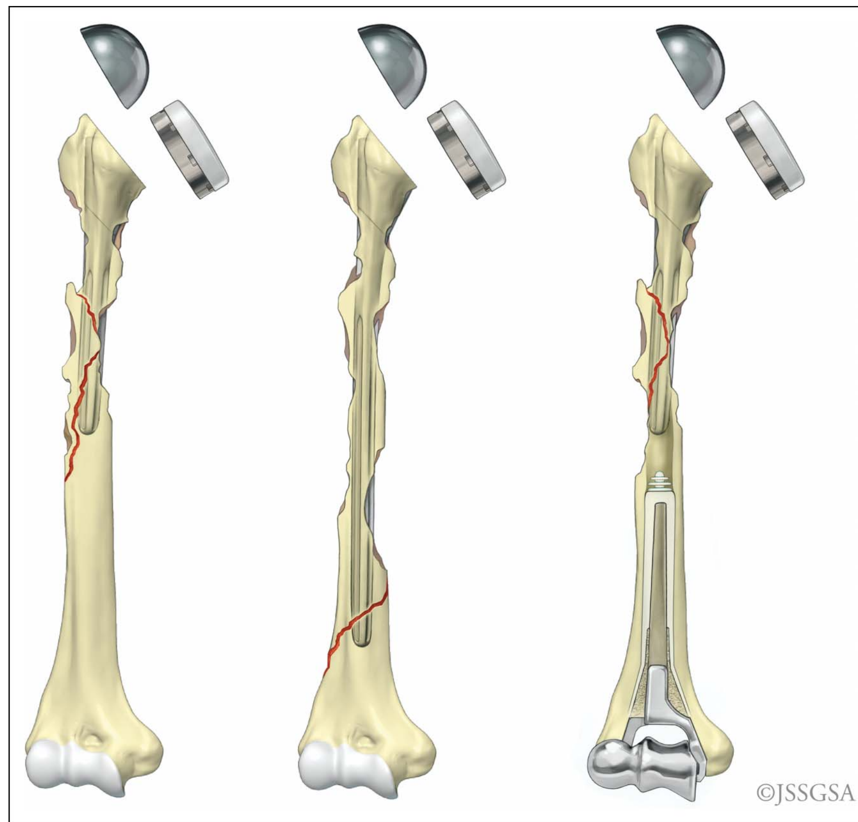


Illustration showing type IIC fractures.

determine premorbid humeral length. An appreciation of the overall humeral length is especially important when considering complex reconstructive options, such as allograft prosthetic composites or modular segmental prostheses. In addition, the proximity of the fracture line to the deltoid insertion is particularly important when considering fixation of fractures in patients with a reverse implant, as partial or complete release of the deltoid for fracture fixation may compromise reverse arthroplasty stability by detensioning the deltoid muscle.

CT is routinely recommended by most surgeons for all revision shoulder arthroplasty procedures, especially to assess the glenoid. CT also allows better understanding of fractures with extensive comminution and better evaluation of the greater tuberosity and remaining proximal humeral bone stock. Axial CT images allow visualization of the humeral stem within the diaphysis, which may allow determine whether fixation screws can be skived around the implant to obtain fixation. In addition, atrophy and fatty infiltration of the rotator cuff may be assessed as well. When fractures complicate an anatomic shoulder arthroplasty, a CT arthrogram may be useful to determine the condition of the rotator cuff and the fixation of the glenoid implant before initiating complex revision surgery.

The value of a complete infection workup before surgical management of a periprosthetic fracture has not been evaluated in detail. Fractures that are a consequence of a clear injury affecting a previously asymptomatic arthroplasty with no evidence of implant loosening probably do not require an infection workup. On the contrary, insufficiency fractures or those with extensive bone loss in a patient with a known history of long-standing implant loosening should probably undergo aspiration of articular fluid for cell count, cultures, and other studies, although the diagnostic yield of these tests is known to be suboptimal for failed shoulder arthroplasty. When the index of suspicion is high for infection, open or arthroscopic biopsies for culture may be considered. Ultrasonography may be considered for the assessment of the rotator cuff and to guide aspiration or synovial biopsy. Magnetic resonance with metal suppression seems to offer limited value over a CT arthrogram. Electromyography with nerve conduction studies is ordered selectively in patients with clinical dysfunction

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 6

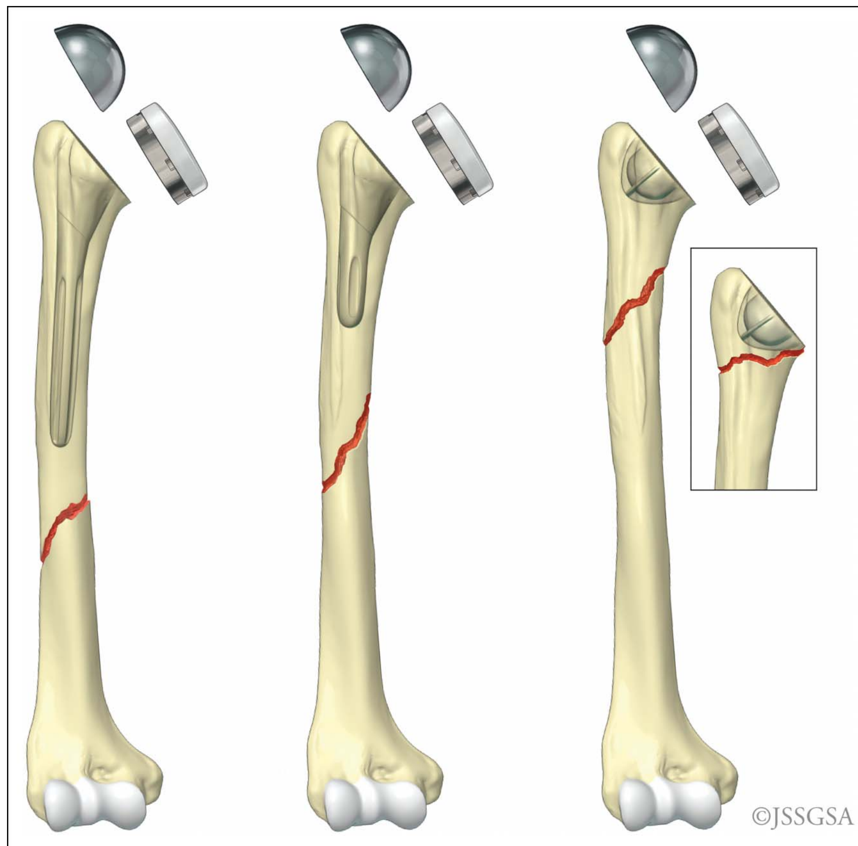


Illustration showing type III fractures.

Table 2. Evaluation of Patients Presenting With a Postoperative Periprosthetic Humeral Fracture After Shoulder Arthroplasty

History and physical
- Index shoulder arthroplasty
  - Indication
  - Components implanted
- Pain and function of the shoulder before the periprosthetic fracture
- Other complications (infection, instability, nerve injury, etc.)
- Comorbidities that may affect healing (smoking, medications, etc.)
- Use of the opposite upper extremity for the patient to demonstrate approximate motion before fracture
- Gentle assessment of deltoid and posterior cuff contraction
- Careful distal neurologic examination, especially in reference to the radial nerve

Radiographs
- High-quality radiographs of the replaced shoulder and whole ipsilateral humerus
- Compare with prior sequential radiographs whenever possible
- Consider radiographs of both humeri with magnifier markers

Advanced imaging and additional testing (selective)
- CT any time revision is considered (preoperative planning)
- CT arthrogram
- Ultrasonography
- Magnetic resonance with metal suppression
- Aspiration and other elements for infection workup
- Albumin and nicotine levels
- Electromyogram with nerve conduction studies

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 7

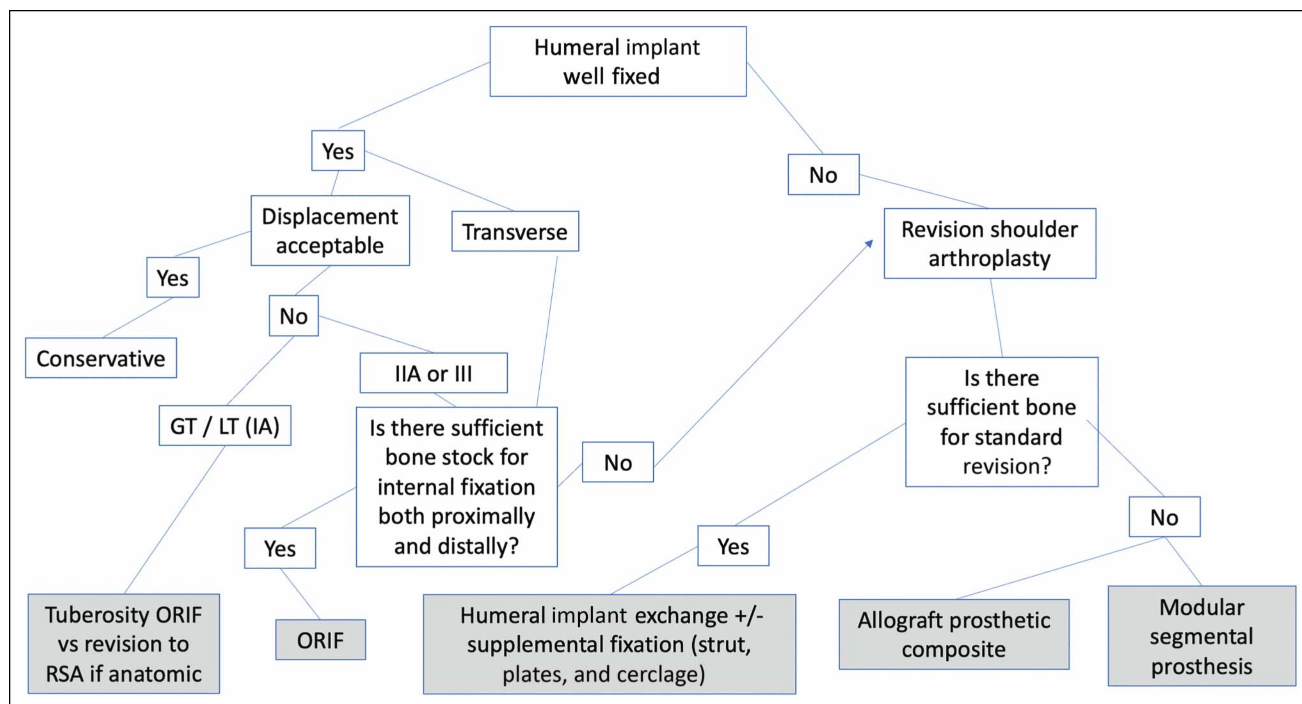


Diagram showing an algorithmic approach to the management of periprosthetic postoperative humeral fractures after shoulder arthroplasty.

of the axillary nerve, radial nerve, brachial plexus, or other nerves of the upper extremity. Albumin and vitamin D as well as nicotine levels may be considered for patients with evidence of malnutrition or chronic use of tobacco products, respectively.

Contemporary Management of Postoperative Periprosthetic Humeral Fractures After Shoulder Arthroplasty

Key Questions for Management

When formulating a periprosthetic fracture treatment plan, a few questions may help frame management strategies: Is the humeral implant well-fixed or loose? For well-fixed implants, is the displacement acceptable? Is the remaining bone stock proximal and distal to the fracture? What is the condition of the rotator cuff if the fracture complicates an anatomic arthroplasty? If fixation is planned, is there enough bone adjacent to the implant to allow acceptable fixation? Is preservation of the deltoid insertion possible with the planned surgery? Is exposure of the radial necessary for safe exposure and management of the fracture? Answering these questions may provide an algorithmic approach to fracture management (Figure 7).

Management Options

Surgeons managing complex postoperative periprosthetic humeral fractures need to be familiar with open reduction and internal fixation principles and revision shoulder arthroplasty techniques depending on the fracture pattern and status of the arthroplasty.

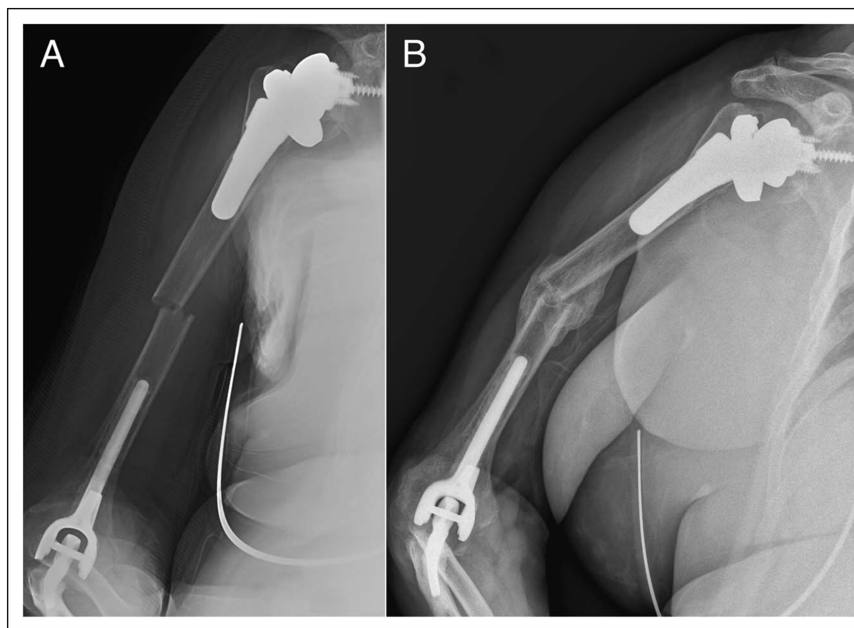
Nonsurgical Treatment

Nonsurgical management is recommended for fractures around a well-fixed humeral implant (IA, IIA, IIIB, and III) provided the residual displacement is acceptable (Figure 8). A substantial proportion of periprosthetic humeral fractures can be initially treated nonsurgically. Fractures with acceptable alignment that are located in the proximal third of the humerus are best treated in a shoulder immobilizer in some degree of external rotation or a collar and cuff. Mid-shaft fractures may be treated in a coaptation splint, followed by a Sarmiento brace. Distal third humeral fractures are managed nonsurgically in a Sarmiento brace, full arm cast, or collar and cuff. Adequate immobilization may be difficult in patients with extremely large body habitus.

Unfortunately, studies published to date indicate that periprosthetic fractures treated nonsurgically take longer to heal than their non-periprosthetic counterparts.[4,8,13] Time to healing after metaphyseal fractures of stemless

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 8



A, Radiograph showing a transverse fracture under a well-fixed humeral implant. **B**, Radiograph showing that nonsurgical management led to fracture union.

implants might be faster. In addition, transverse fractures (IIAt) seem to carry a higher risk of nonunion, and some surgeons have a lower threshold to recommend surgical management for this fracture type.[5] Alternatively, some surgeons may elect to treat certain fractures around loose humeral implants nonsurgically (IB and IIB) in an attempt to let some healing occur that might facilitate a revision procedure planned for later. However, care must be taken when managing fractures nonsurgically when the final plan is to conduct a revision of the loose humeral stem after healing. In these circumstances, any subtle malunion of a diaphyseal fracture may preclude passage of a longer stemmed revision implant if the fracture does not heal; however, if the fracture was to heal with residual malunion, modern short-stem implants may allow later revision with implantation proximal to the deformed humerus. Finally, failure of healing progression after 3 to 6 months of nonsurgical treatment may become an indication for surgical management.

Internal Fixation

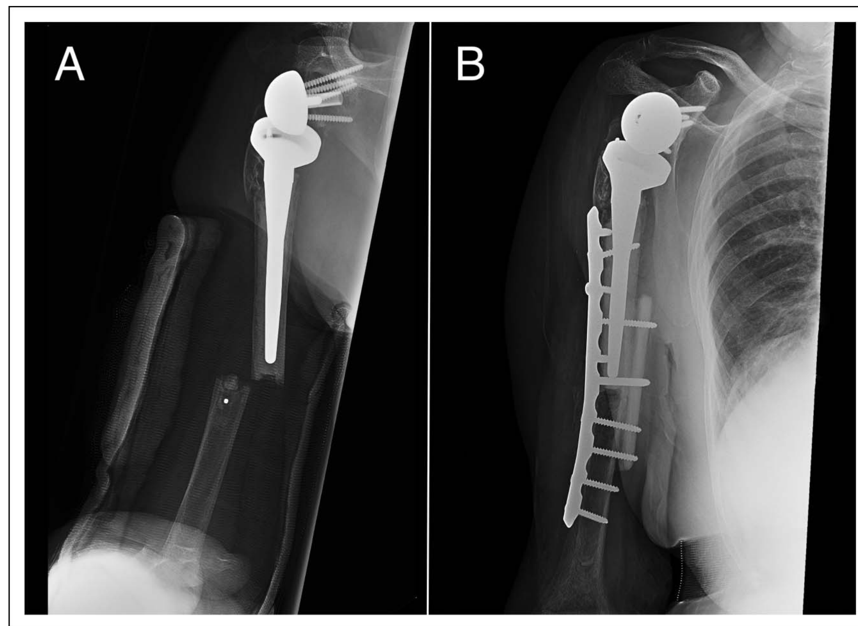
Internal fixation is recommended for fractures around a well-fixed humeral implant either (1) presenting with excessive displacement or (2) those that fail to heal after a trial of nonsurgical treatment. Displaced greater tuberosity fractures may be fixed with open or arthroscopically assisted techniques using tape or suture fixation with or without plate and screw augmentation. Open reduction and internal fixation with compression plating is the most common modality considered for excessively displaced type IIA and III fractures. The authors have a low threshold to augment plate fixation with a cortical strut allograft (Figure 9). Fixation of the plate to the humerus at the level where the plate overlaps with the stem may be achieved with nonlocking bicortical screws angulated to miss the stem (skive screws); unicortical locking screws; or cerclage wires, cables, or tapes through the plate and around the humerus. When using circumferential wire/cable/tape fixation, great care must be taken to prevent injury to the radial nerve. Very proximal fractures around short-stem and stemless implants may benefit from the use of dedicated periarticular proximal humerus fracture plates.

Revision Shoulder Arthroplasty

Revision shoulder arthroplasty is considered for (1) fractures around a loose humeral implant (IB, IIB, and IIC) and (2) fractures where the remaining bone stock proximally or distally makes it impossible to achieve adequate plate fixation. The second circumstance is more likely to occur when type IB or IIB fractures complicate a short-stem and stemless prosthesis. Depending on the location and comminution of the fracture and the nature of the implant to be revised, we think of these revision procedures as "*basic*," "*standard*," or "*complex*."

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 9



Radiographs showing plate fixation and strut augmentation for a type IIAt periprosthetic fracture. **A**, Displaced fracture. **B**, Postoperative radiograph.

An example of a *"basic" revision* would be revision of a loose stemless or short-stem prosthesis with a type IIB fracture. Implantation of a standard-length stem with press-fit fixation (or cemented if needed) may be used. Typically, the fractured fragments and tuberosities are sutured or cerclage-wired around the prosthesis. Rarely, in cases with a larger greater tuberosity fracture, lateral plate fixation may be indicated. The utilization of stems with fracture fixation features and stems designed for diaphyseal fixation may be advantageous. The keys for success in these procedures include achieving adequate primary stability of the revision prosthesis (axially and rotationally) and facilitating healing of the tuberosities to restore the function of the rotator cuff. Most surgeons would select a reverse configuration when conducting these revisions.

An example of a *"standard" revision* would be the management of a type IIB fracture in the setting of a standard-length stem. Most surgeons would favor revision to a humeral implant long enough to bypass the fracture site and obtain distal fixation. The stem itself may be able to stabilize the fracture adequately as an "intramedullary nail" or additional fixation of the fracture may be needed. Conical fluted stems designed for diaphyseal fixation have become the workhorse for the management of similar fractures after hip arthroplasty, and they are likely to become the preferred implant in the humerus as well.

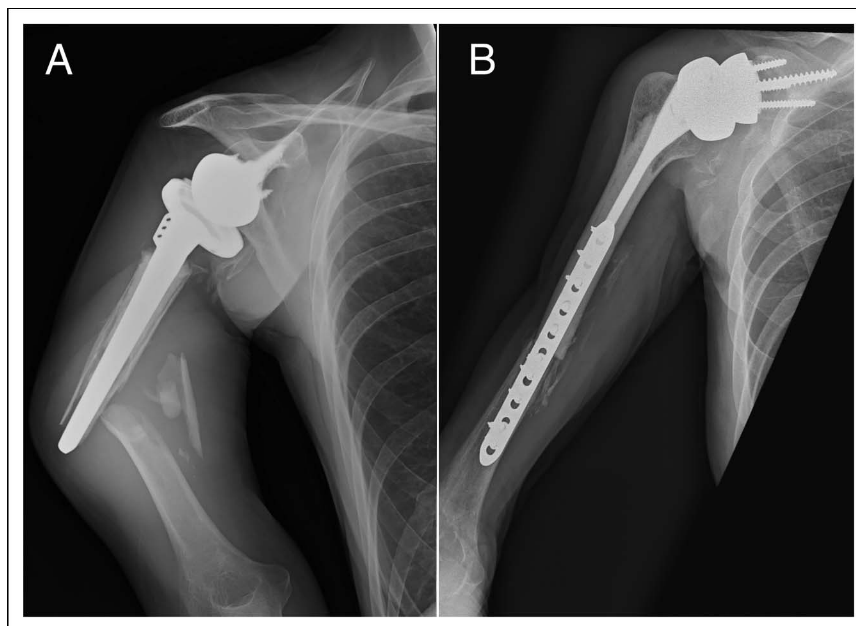
More complex reconstructions are required for type IIC fractures, which present with severely compromised bone stock requiring special reconstructive techniques. These *"complex" revision* procedures may involve implantation of a modular segmental "tumor" prosthesis, reconstruction with an allograft prosthetic composite (Figure 10), and in extreme cases, a total humeral arthroplasty with a shoulder arthroplasty proximally and an elbow arthroplasty distally. The relative benefits and comparative outcomes of these complex reconstructive techniques specifically for periprosthetic humeral fractures are yet to be determined. Finally, rare circumstances may arise when a staged procedure is most appropriate, which may involve fixation of the fracture first, followed by delayed second-stage revision arthroplasty.

Reported Outcomes

Several authors have reported on the outcome of periprosthetic humeral fractures associated with anatomic TSA. Interestingly, all of these studies include a very small number of postoperative humeral fractures, between 5 and 16. Wright and Cofield[8] reported on nine periprosthetic humeral fractures after anatomic TSA. Of the seven fractures treated nonsurgically, four healed and three did not. Surgery was successful in two fractures with excessive initial displacement and two of the

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

Figure 10



Radiographs showing a periprosthetic fracture with implant loosening and infection managed with a staged revision to an allograft prosthetic composite. **A**, Preoperative radiograph before resection. **B**, Postoperative radiograph after allograft prosthetic composite reconstruction.

nonunions. Kumar et al[4] expanded on the experience from the same institution and reported on 16 periprosthetic humeral fractures after anatomic total shoulder arthroplasty (TSA). Five fractures treated surgically healed; 11 fractures were treated nonsurgically and 5 of these eventually required surgery. The average time to union was 6 months for fractures treated nonsurgically and 9 months for fractures treated surgically. Campbell et al reported on the outcome of 21 periprosthetic humeral shaft fractures, of which only 5 occurred postoperatively; four of these 5 fractures healed with nonsurgical treatment at a mean time of 3.5 months.[7] Worland et al reported on six fractures, five of which were managed surgically; all fractures healed.[5]

Andersen et al reported on the largest series to date of postoperative periprosthetic humeral shaft fractures treated surgically.[11] These authors reported on 36 fractures that occurred after anatomic (19 shoulders) or reverse (17 shoulders) arthroplasties treated with internal fixation (17 shoulders) or revision arthroplasty (19 shoulders). Seven of these patients had initially been treated nonsurgically. For the 17 fractures treated with

Table 3. Recent Studies Published on the Outcome of Periprosthetic Postoperative Humeral Fracture Management

Study	Implant	n	Management	Outcome	Complications
García-Fernández et al[12]	RSA	4	ORIF—3 Conservative—1	100% union	Radial nerve palsy—1
Kurowicki et al[18]	HA—2 TSA—2 RSA—1	5	ORIF	100% union	PJI—1
Saltzman et al[19]	RSA	1	ORIF	Union	—
Schoch et al[20]	TSA—4 RSA—1	5	ORIF	Union	—
Ragusa et al[13]	RSA	5	Conservative	Union 4/5	—
Rollo et al[21]	RSA	30	ORIF +/− stem revision	100% union	Intraoperative (1) and postoperative (1) fracture

ORIF = open reduction and internal fixation, HA = hemiarthroplasty, PJI = periprosthetic joint infection.

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.

plate fixation, allograft strut augmentation was added in eight shoulders, and all fractures healed at an average time of 7 months, although two shoulders (12%) required distal plate extension for failure of fixation. For fractures treated with revision arthroplasty, bulk allograft was used in almost all shoulders (17) and a long-stem prosthesis in 14 shoulders; all but one fracture healed at an average time of 8 months, and additional complications included implant dissociation, dislocation, stem loosening, and another periprosthetic fracture. More recently, a few additional studies have been reported (Table 3).

Summary and Future Directions

Most studies on periprosthetic postoperative humeral fractures after shoulder arthroplasty have reported occurrence rates between 0.5% and 3%. The increased utilization of shoulder arthroplasty combined with implantation in older patients and increase in life expectancy will translate into a larger burden of care related to periprosthetic humeral fractures. The field of shoulder arthroplasty has changed dramatically, in particular, regarding the use of RSA and the introduction of short-stem and stemless humeral implants. Commonly used classification schemes still used today are not comprehensive enough to capture fracture types encountered in current practice. The Unified Classification of periprosthetic fractures needs to be substantially expanded to provide guidance into the management of periprosthetic humeral fractures after shoulder arthroplasty.

A substantial number of periprosthetic humeral fractures can be successfully treated nonsurgically. Excessively displaced fractures and those associated with a loose humeral implant are typically addressed surgically. Internal fixation is likely to be successful provided the humeral implant is well fixed and adequate fracture stability can be achieved. Revision procedures for the management of periprosthetic fractures with a loose humeral implant requires mastery of several reconstructive techniques, including implant revision, strut augmentation, supplemental internal fixation, modular segmental prostheses, and allograft prosthetic composites.

References

References printed in **bold type** are those published within the past 5 years.

1. Farley KX, Wilson JM, Kumar A, et al.: Prevalence of shoulder arthroplasty in the United States and the increasing burden of revision shoulder arthroplasty. *JB JS Open Access* 2021;6:e20.00156.

2. Fram B, Elder A, Namdari S: Periprosthetic humeral fractures in shoulder arthroplasty. *JBJS Rev* 2019;7:e6.

3. Singh JA, Sperling J, Schleck C, Harmsen W, Cofield R: Periprosthetic fractures associated with primary total shoulder arthroplasty and primary humeral head replacement: A thirty-three-year study. *J Bone Joint Surg Am* 2012;94:1777-1785.

4. Kumar S, Sperling JW, Haidukewych GH, Cofield RH: Periprosthetic humeral fractures after shoulder arthroplasty. *J Bone Joint Surg Am* 2004; 86:680-689.

5. Worland RL, Kim DY, Arredondo J: Periprosthetic humeral fractures: Management and classification. *J Shoulder Elbow Surg* 1999;8:590-594.

6. Cameron B, Iannotti JP: Periprosthetic fractures of the humerus and scapula: Management and prevention. *Orthop Clin North Am* 1999;30: 305-318.

7. Campbell JT, Moore RS, Iannotti JP, Norris TR, Williams GR: Periprosthetic humeral fractures: Mechanisms of fracture and treatment options. *J Shoulder Elbow Surg* 1998;7:406-413.

8. Wright TW, Cofield RH: Humeral fractures after shoulder arthroplasty. *J Bone Joint Surg Am* 1995;77:1340-1346.

9. Sanchez-Sotelo J: Current concepts in humeral component design for anatomic and reverse shoulder arthroplasty. *J Clin Med* 2021;10: 5151.

10. Della Rocca GJ, Leung KS, Pape HC: Periprosthetic fractures: Epidemiology and future projections. *J Orthop Trauma* 2011;25(suppl 2): S66-S70.

11. Andersen JR, Williams CD, Cain R, Mighell M, Frankle M: Surgically treated humeral shaft fractures following shoulder arthroplasty. *J Bone Joint Surg Am* 2013;95:9-18.

12. García-Fernández C, Lópiz-Morales Y, Rodríguez A, López-Durán L, Martínez FM: Periprosthetic humeral fractures associated with reverse total shoulder arthroplasty: Incidence and management. *Int Orthop* 2015;39: 1965-1969.

13. Ragusa PS, Vadhera A, Jang JM, Ali I, McFarland EG, Srikumaran U: Nonoperative treatment of periprosthetic humeral shaft fractures after reverse total shoulder arthroplasty. *Orthopedics* 2020;43: e553-e560.

14. Atoun E, Van Tongel A, Hous N, et al.: Reverse shoulder arthroplasty with a short metaphyseal humeral stem. *Int Orthop* 2014;38:1213-1218.

15. Groh GI, Heckman MM, Wirth MA, Curtis RJ, Rockwood CA Jr: Treatment of fractures adjacent to humeral prostheses. *J Shoulder Elbow Surg* 2008;17:85-89.

16. Kirchhoff C, Beirer M, Brunner U, Buchholz A, Biberthaler P, Crönlein M: Validation of a new classification for periprosthetic shoulder fractures. *Int Orthop* 2018;42:1371-1377.

17. Duncan CP, Haddad FS: The unified classification system (UCS): Improving our understanding of periprosthetic fractures. *Bone Joint J* 2014;96-b:713-716.

18. Kurowicki J, Momoh E, Levy JC: Treatment of periprosthetic humerus fractures with open reduction and internal fixation. *J Orthop Trauma* 2016; 30:e369-e374.

19. Saltzman BM, Leroux T, Collins MJ, Arns TA, Forsythe B: Short stem reverse total shoulder arthroplasty periprosthetic type A fracture. *Orthopedics* 2017;40:e721-e724.

20. Schoch B, Mehta S, Namdari S: Surgical fixation of periprosthetic humerus fractures using an extension plate: Surgical technique and report of 5 cases. *J Orthop Trauma* 2017;31:e432-e435.

21. Rollo G, Biserni M, Huri G, et al.: Strut graft vs. traditional plating in the management of periprosthetic humeral fractures: A multicentric cohort study. *Med Glas (Zenica)* 2020;17:490-497.

Copyright © the American Academy of Orthopaedic Surgeons. Unauthorized reproduction of this article is prohibited.