CHAPTER 22

Proximal Humerus Fractures: Hemiarthroplasty Versus Reverse Total Shoulder Arthroplasty

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DEFINITION

- **Proximal humerus fractures** are common **shoulder** injuries, which comprise approximately 5% of all **fractures**.[1,2]
  - Majority of injuries result from a low-energy fall in the older patient population.[3,4]
    - Third most common **fracture** sustained by patients older than the age of 65 years.[5]
    - Incidence increases substantially after the age of 60 years,[4,6,7] with the highest age-specific incidence occurring in women between the ages of 80 and 89 years.[3]
    - Lauritzen and colleagues[8] have reported that women older than the age of 60 years have an 8% lifetime risk of sustaining a **proximal humerus fracture**.
- The projected incidence of **proximal humerus fractures** is anticipated to triple by the year 2030.[9]

ANATOMY

- The proximal humerus is divided into four main parts based on typical **fracture** patterns.[10]
  - The proximal humerus comprises the articular surface, the greater tuberosity, the lesser tuberosity, and the humeral shaft.
- The long head of the biceps tendon runs in the bicipital groove, which is located between the greater and lesser tuberosities.
- The mean neck-shaft angle of the proximal humerus is approximately 130° to 135°.[11,12]
- Humeral retroversion is typically 20° to 30° retroverted (mean 25°) relative to the epicondylar axis of the elbow with a standard deviation of 10°.[11]
- The articular surface of the superior portion of the humeral head is approximately 8 mm superior to the greater tuberosity.[11]
- Knowledge of the muscular attachments to the proximal humerus is essential for understanding the deforming forces following injury (Figure 22.1).
  - The superior and posterosuperior rotator cuff, which consists of the supraspinatus, infraspinatus, and the teres minor, attach to separate aspects of the greater tuberosity.
    - The deforming force of these muscles typically results in posterior superior displacement of the greater tuberosity fragment.
  - The subscapularis attaches to the lesser tuberosity.
    - The deforming force results in medial displacement of this fragment.
  - The pectoralis major has a strong and broad insertion along the anterior aspect of the humeral shaft just lateral to the biceps tendon and bicipital groove.
    - **Fractures** of the surgical neck frequently result in proximal and medial displacement of the humeral shaft secondary to the deforming force of the pectoralis major.
  - The deltoid attaches to the lateral aspect of the humerus.
    - The strong pull of the deltoid can cause proximal translation of the humeral shaft with **proximal humerus fractures**.
- The vascular perfusion to the proximal humerus is derived from branches of the axillary artery.
  - The ascending branch of the anterior humeral circumflex artery and arcuate arteries branch off the axillary artery and traverse from medial to lateral across the inferior border of the subscapularis muscle.
    - The anterior humeral circumflex artery is accompanied by two veins, which are often referred to as the "three sisters."

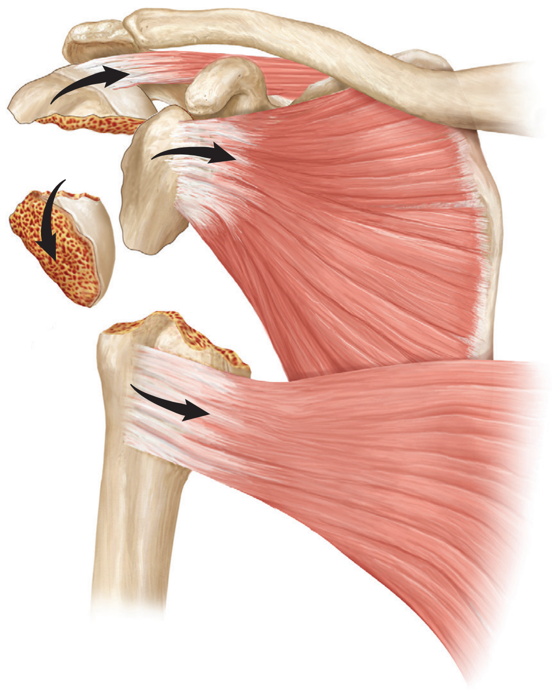

FIGURE 22.1 Muscular attachments to the proximal humerus result in characteristic deforming forces.

- The anterior humeral circumflex artery wraps around the humerus posterolaterally to anastomose with the posterior humeral circumflex artery.
- The posterior humeral circumflex artery also branches off the axillary artery and travels with the axillary nerve through the quadrilateral space of the **shoulder**.
  - Quantitative MRI analysis of the humeral head blood supply by Hettrich and colleagues[13] suggests that the posterior humeral circumflex artery supplies approximately 64% of the humeral head blood supply and thus the main supply to the proximal humerus.

PRINCIPLES IMPORTANT TO PROCEDURE

- Determining the best treatment strategy for patients with **proximal humerus fracture** can be challenging and is an area of continued controversy.
- The vast majority of **proximal humerus fractures** can be managed nonoperatively with satisfactory outcomes.[3,14,15]
  - In addition to nondisplaced or minimally displaced **fractures**, valgus-impacted **fractures** with minimal greater tuberosity displacement and two-part surgical neck **fractures** have demonstrated similar outcomes when compared with those of operative treatment in elderly patients.[16-20]
- Displaced three- and four-part **fractures**, head split **fractures**, and fracture-dislocations are associated with poorer outcomes and higher complications following nonoperative treatment.[14,21]
  - Diminished bone density of the proximal humerus[22] coupled with the increasing prevalence of rotator cuff pathology in the elderly population[23-25] adds additional complexity to operative decision-making.
- One must consider the patient's age, functional status, **fracture** personality, bone quality, and overall goals of treatment in order to select the best treatment for the individual patient.
  - For younger patients, open reduction and internal fixation (ORIF) is almost always warranted if the patient has a surgical **fracture**.
  - For older patients with poorer bone quality and lower functional demands, ORIF may not be the best option.
    - Jost and colleagues reported on 121 patients (mean age, 59 years old) following ORIF of **proximal humerus fractures** with locking plate fixation.[26]
      - 80% of patients had three-or four-part **fractures**.
      - At follow-up, 57% of patients with a three-or four-part **fractures** demonstrated screw cut out, with over 50% requiring a salvage **arthroplasty**.[26]
    - Owsley and Gorczyca[27] reported 43% screw cut out in patients older than the age of 60 years treated with ORIF.
    - Higher rates of reoperation have been reported in a recent systematic review comparing **proximal humerus fractures** treated with ORIF compared with **hemiarthroplasty** or **reverse shoulder arthroplasty**.[28]
- Several factors need to be considered if an **arthroplasty** is going to be performed for a **proximal humerus fracture**.
  - Younger patients with higher physical demands or those who may not be compliant make poor candidates for **reverse shoulder arthroplasty**.
  - The age of the patient is also of critical importance, because elderly patients are more likely to have degenerative rotator cuff pathology, which may compromise outcomes following a **hemiarthroplasty**.[19,23-25,29]
    - Robinson and colleagues[29] reported a large series of 138 patients with **proximal humerus fractures** treated with hemiarthoplasty and noted that age greater than 70 years had the strongest correlation with poor outcomes at 1 year follow-up.
    - Successful outcomes following **hemiarthroplasty** require reestablishing anatomic prosthetic height, version, and anatomic reduction and healing of the tuberosities.
      - Relative indications and contraindications for **hemiarthroplasty** and **reverse shoulder arthroplasty** are presented in Tables 22.1 and 22.2, respectively.

TABLE 22.1

Relative Indications and Contraindications for Hemiarthroplasty for Proximal Humerus Fractures

Indications for Hemiarthroplasty
• **Fracture** with head split or substantial humeral head comminution not amenable to ORIF
• Impacted **fracture** of the humeral head or chronic locked dislocation with articular involvement >50%
• No tuberosity comminution
• Intact rotator cuff
• Typically between 50 and 70 y old
Contraindications for Hemiarthroplasty
• Significant tuberosity comminution
• Age <50 (relative)
• Prior evidence of rotator cuff pathology

TABLE 22.2

Relative Indications and Contraindications for Reverse Shoulder Arthroplasty for Proximal Humerus Fractures

Indications for Reverse Shoulder Arthroplasty
• Patients > 70 y old
• Three- and four-part **fractures**
• **Fractures** with significant comminution of the greater tuberosity
• Articular head splitting **fractures**
• Locked fracture/dislocations with significant comminution
Contraindications for Reverse Shoulder Arthroplasty
• High fall risk (Dementia, Parkinson disease, etc)
• No functioning deltoid
• Concomitant glenoid/scapular **fracture** that precludes baseplate placement

Pathogenesis

- The vast majority of **proximal humerus fractures** occur in elderly women following a low-energy fall.[3,4]
  - Approximately 50% are nondisplaced or minimally displaced.[3,30]
  - **Fractures** resulting from a low-energy ground level fall typically result from either force transmission through the humerus into the glenoid following a fall on an outstretched hand or from a direct impact to the **shoulder**.
- **Proximal humerus fractures** occurring in younger patients tend to result from higher-energy mechanisms and are associated with more significant bone and soft-tissue damage.

History/Physical Findings

- A thorough history and physical examination is always imperative prior to deciding on operative intervention.
- It is critical to ascertain the mechanism of injury as well as the patient's baseline functional status and medical comorbidities.
  - A history of falls or medical conditions associated with a high fall risk such as Parkinson disease or dementia may favor nonoperative treatment for certain patients.
- The presence of anteceding rotator cuff disease may alter decision-making if an **arthroplasty** is warranted.
- Concomitant injuries to the extremity, such as distal radius **fracture** or elbow **fractures**, are commonplace and warrant careful examination.
- A detailed neurovascular examination should assess neurologic status as well as possible vascular injury, which is rare but potentially devastating.[31]
  - If **reverse shoulder arthroplasty** is being considered, assessment of axillary nerve function is critical, and can be assessed by testing sensation over the lateral aspect of the **shoulder** and assessing firing of the anterior, medial, and posterior deltoid fibers by palpation.
    - Electromyographic changes in axillary nerve conduction following **proximal humerus fractures** can occur in up to 58% of patients.[32]
    - Axillary nerve neuropraxia is not a contraindication to **reverse shoulder arthroplasty**; however, it is helpful to counsel the patient that recovery of their **shoulder** function following surgery may be more prolonged.

Diagnostic Studies

- Evaluation of suspected **proximal humerus fractures** starts with plain radiographs of the **shoulder**, arm, and elbow.
  - The typical **shoulder** series consists of a true AP or Grashey view, regular AP, scapular-Y view, and an axillary lateral view (Figure 22.2).
  - The axillary view is critical to assess the position of the greater tuberosity, the glenoid articular surface, and for dislocation of the glenohumeral joint.
  - A Velpeau view also suffices to assess for joint reduction in instances where an axillary radiograph cannot be obtained.
- In **fractures** where operative intervention is being considered, computed tomography (CT) is often obtained to better characterize the **fracture** pattern.
  - CT scans can better assess for suspected head splitting **fractures** and tuberosity comminution, which may influence one to opt for **arthroplasty** (Figure 22.3).
  - Three-dimensional CT reconstruction can provide additional information regarding **fracture** pattern and tuberosity comminution, which better facilitates preoperative planning.

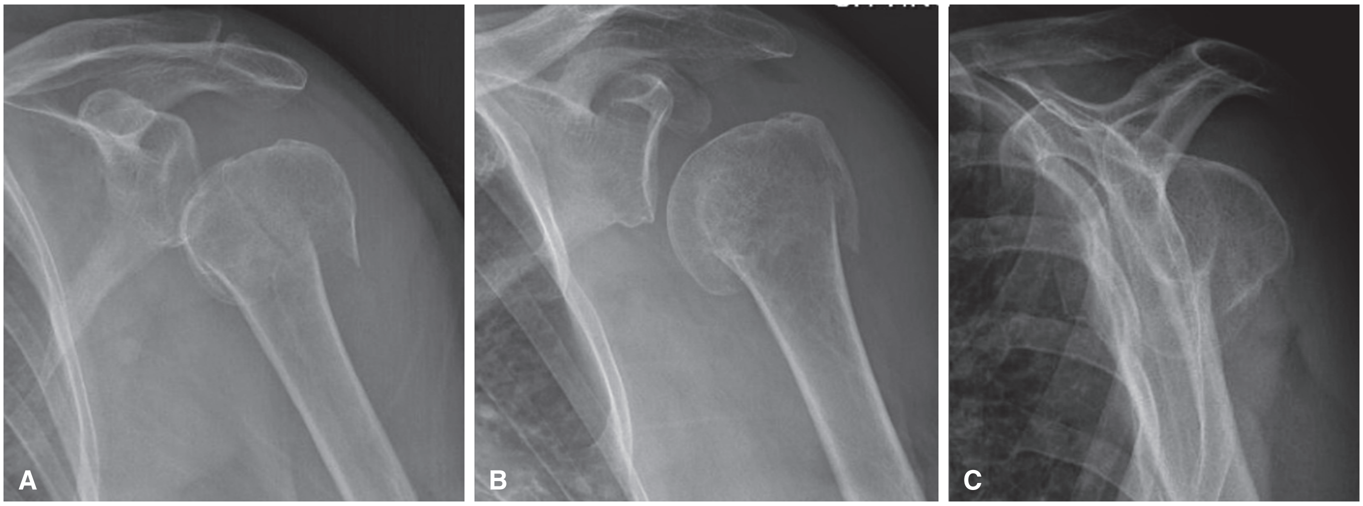

FIGURE 22.2 Anteroposterior (A), Grashey (B), and scapular-Y (C) radiographs of a left **proximal humerus fracture**.

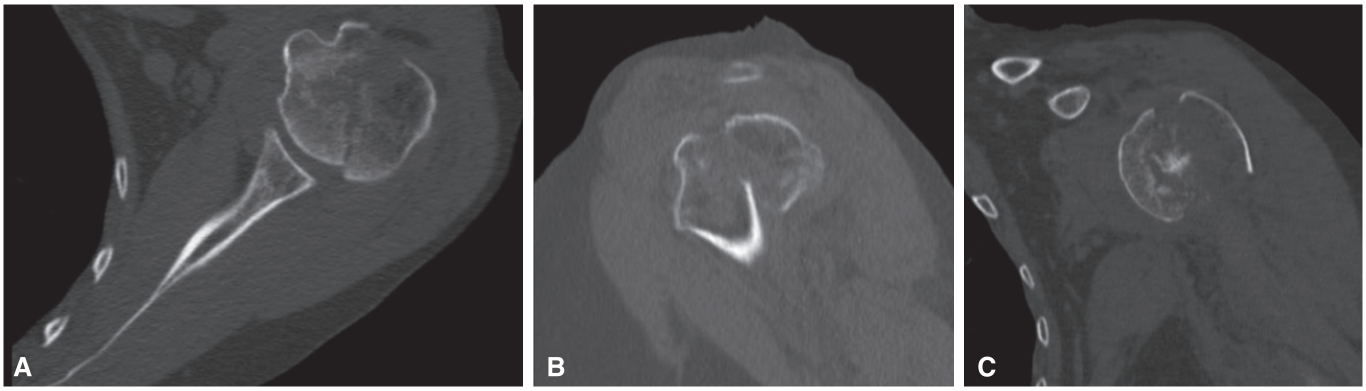

FIGURE 22.3 Axial (A), sagittal (B), and coronal (C) CT images of a left **proximal humerus fracture** with an articular splitting **fracture** with tuberosity comminution.

Diagnosis

- The diagnosis of **proximal humerus fractures** is usually relatively straight forward and can be made on plain radiographs. However, CT can provide more robust information regarding the **fracture** and aid in surgical decision-making.
- Clinically, the patient often has significant **shoulder** pain, swelling, ecchymosis, and a reluctance to use the arm.
- The most widely used classification system for **proximal humerus fractures** is the Neer classification.[10,33]
    - Based on identification of displaced fragments of the proximal humerus, defined as displacement >1 cm or angulation >45°.
    - Intraobserver and interobserver reliability using this classification system is reported as good.[34,35]

SURGICAL MANAGEMENT

Reverse Shoulder Arthroplasty

- Preoperative planning for **reverse shoulder arthroplasty** for **fracture** includes routine plain radiographs and a CT scan with three-dimensional reconstruction.
    - CT is helpful to gain an enhanced understanding of the tuberosities, the articular surface of the head, as well as the glenoid morphology.
    - The degree of tuberosity comminution is important for surgical reconstruction but for also determining the likelihood of being able to obtain an anatomic reduction and of achieving tuberosity healing.
    - Three-dimensional reconstructed CT scans have demonstrated significant improvement over two-dimensional CT scans in assessing glenoid morphology,[36,37] which is necessary for accurate baseplate placement.

Hemiarthroplasty

- The preoperative planning, surgical approach, management of the tuberosities, and biceps tendon when performing **hemiarthroplasty** for **proximal humerus fractures** are similar to those previously described for **reverse shoulder arthroplasty**.
  - One important difference when performing **hemiarthroplasty** is that the coracoacromial ligament is maintained to preserve the coracoacromial arch.
  - Successful outcomes following **hemiarthroplasty** for **proximal humerus fracture** are intimately correlated to the anatomic reduction and healing of the tuberosities.
  - Being critical of reproducing humeral head size, implant height and version are essential for repairing the tuberosities without undue tension and maximizing patient outcome.
- Selecting the appropriate humeral head size is an important step during **hemiarthroplasty** for **fracture**.
  - After mobilization of the tuberosities and extraction of the humeral head, we use the native articular segment to best match the prosthetic trial based on depth, width, and radius of curvature.
  - Unless there is a perfect size match, it is always better to slightly undersize the component.
    - A humeral head that is too large will increase the offset of the prosthesis and likely force the surgeon to repair the tuberosities with excessive amounts of tension, which may compromise healing.
    - Additionally, choosing a humeral head that is too large can lead to overstuffing the joint, which may restrict motion and overtime may lead to progressive rotator cuff dysfunction (Figure 22.4).
    - If intraoperative fluoroscopy is used, a "best-fit" circle method as described by Alolabi and colleagues[38] can assess for overstuffing of the joint.
- In addition to best matching the articular segment characteristics, it is critical to reestablish correct prosthesis height.
  - Excessive lengthening of the arm by more than 10 mm can cause excessive tension on the rotator cuff and jeopardizes tuberosity healing.[39]
  - One technique that is often helpful for this is to use "jigsaw" method,[40] whereby the native humeral head is provisionally reduced to the shaft to serve as a template for prosthetic replacement.
  - This serves as a reliable method for accurately assessing native height, which can then be measured from other landmarks such as the pectoralis major tendon.
  - Several authors[41,42] have reported the mean distance from the superior aspect of the humeral head to the upper border of the pectoralis major tendon to be approximately 5.6 cm.

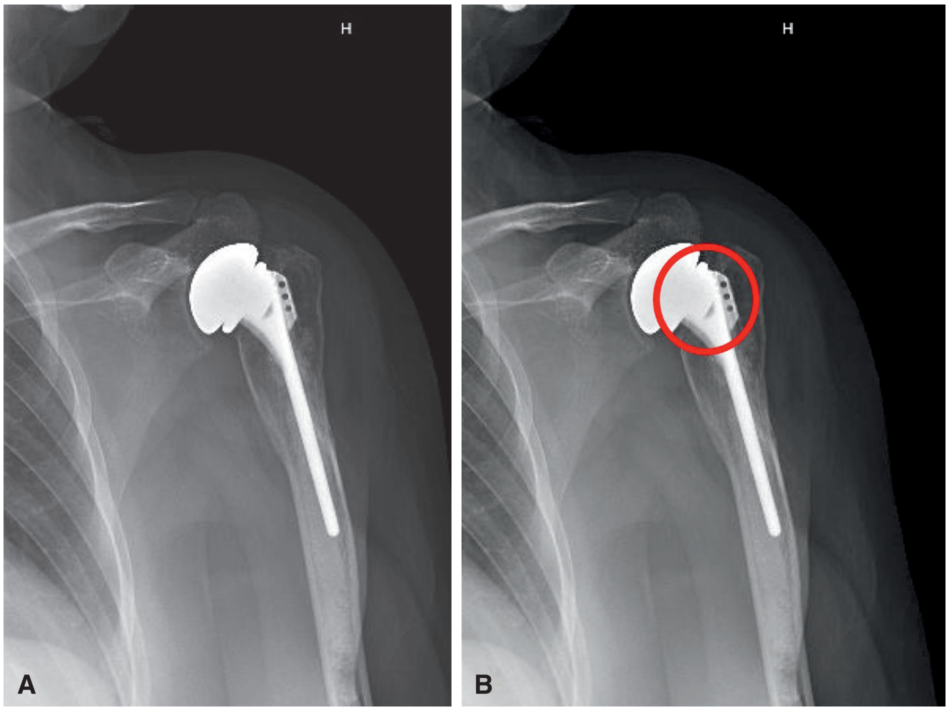

FIGURE 22.4 This AP x-ray is of a patient who had a **hemiarthroplasty** performed for **proximal humerus fracture** approximately 20 years prior (A). Using a "best-fit" circle method as described by Alolabi and colleagues,[38] it appears that the implant was oversized and overstuffed the joint (B). At the time of revision surgery the patient was completely rotator cuff–deficient and was revised to a **reverse shoulder arthroplasty**. [AU2]

- Surgeon preference and comfort should be used to best reproduce the patient's anatomy resulting in the most anatomic prosthetic reconstruction.
- Other landmarks that can be used are the medial calcar and the tuberosity position.
  - If the medial calcar is intact, the medial collar of the prosthesis should be flush with this segment of bone.
  - In cases where there is comminution of the medical calcar that cannot be accurately reconstructed with the jigsaw method, the height of the tuberosity relative to the height of the prosthesis should be approximately 10 mm.[43]
- Reproducing native humeral retroversion is an essential step in **hemiarthroplasty** for **fracture**.
  - Component version has an important effect on tuberosity healing following **hemiarthroplasty**[39] and is more forgiving when performing a **reverse shoulder arthroplasty**, where tuberosity healing is not as critical for a successful outcome.
  - Normal humeral retroversion can vary substantially, as much as from 0° to 50°[11]; therefore, when performing **hemiarthroplasty**, matching the patient's natural version is essential for accurate tuberosity reduction.
    - The authors prefer to use stem-specific instrumentation placing the stem in 20° of retroversion.
  - The jigsaw method as described above can often help reestablish native retroversion.
  - An implant that is excessively retroverted will result in an overly tensioned greater tuberosity fragment in internal rotation and an overly tensioned lesser tuberosity fragment with external rotation.

TECHNIQUES

Reverse Shoulder Arthroplasty

- The patient is placed in the beach-chair position following the induction of general anesthesia with the back elevated approximately 60°.
- A wedge pillow placed underneath the thighs helps facilitate the seated position and provide stability.
- The operative extremity is positioned over the lateral aspect of the table, which allows for unencumbered adduction and extension of the arm.
  - This is critical to allow for humeral canal access and instrumentation free of interference from the patient's head.
- Perioperative antibiotics are administered per protocol.
  - Some surgeons prefer to use vancomycin in addition to cefazolin to help prophylaxis against *Propionibacterium acnes*; however, insufficient literature exist to support this practice at the current time.
- The arm is then prepped and draped according to standard operating procedure.
- A hydraulic arm holder is preferred throughout the case to aid in positioning of the extremity.
- Our preference is to use the deltopectoral approach, which reliably results in excellent exposure of the **shoulder**.
- The anterosuperior approach can also be utilized for this procedure; however we tend not to use this approach to avoid deltoid detachment.[44]

Surgical Approach

- An approximately 10 cm incision from just lateral to the coracoid process toward the deltoid insertion is made.
- The knife used for the skin incision is taken off the field (avoiding deep wound contamination with *Cutibacterium acnes*), and two retractors are placed in the subcutaneous tissues.
- Electrocautery is used to dissect down to but not through the deltopectoral fascia.
- Care is taken to identify the cephalic vein, which we tend to retract laterally as this disrupts less tributaries to the deltoid.
- The deltopectoral interval is then identified and entered at the superomedial aspect and then developed through a combination of blunt dissection and electrocautery.
- The pectoralis major tendon is identified, and 1 to 2 cm of the tendon is released from its most superior border.
- The underlying long head of the biceps tendon can then be identified and a soft-tissue tenodesis is routinely performed at this level to the pectoralis major tendon.
- The remaining proximal aspect of the biceps tendon is an important landmark, as the greater tuberosity fragment is often posterior to the biceps tendon and the lesser tuberosity is medial to the tendon at the level of the groove.
- Releasing the proximal aspect of the pectoralis major tendon also allows for the proximal aspect of the latissimus dorsi tendon to be identified, which serves as an excellent landmark for the inferior extent of the subscapularis.
- The pectoralis major is then retracted medially while the deltoid is retracted laterally.
- A blunt human is placed under the coracoacromial ligament to aid in exposure. [AU1]
- The coracoclavicular ligament is resected off the lateral coracoid.
- In the posttraumatic **shoulder**, the subdeltoid space is often adhered to the lateral aspect of the proximal humerus.

- A finger placed deep to the deltoid and lateral to the humerus can help mobilize this tissue plane.
- Next, we identify the lateral border of the conjoined tendon and release the clavipectoral fascial lateral to the conjoined tendon to allow for mobilization.

Tuberosity Mobilization

- After evacuation of fracture hematoma and bursal tissue, the **fracture** fragments are then mobilized.
- A Cobb elevator can be helpful to mobilize the greater tuberosity fragment, which is often more posterior-superiorly displaced.
- Four sets of heavy nonabsorbable sutures are placed around the greater tuberosity at the bone-tendon junction (two through the infraspinatus and two through the teres minor) and one #5 Ethibond around the lesser tuberosity. These suture sets serve as traction sutures for manipulation of the fragments and for later repair (Figure 22.5).
  - Two of the sutures will be used to secure the tuberosity to the prosthesis, while the other two will be used to achieve horizontal fixation with the lesser tuberosity.
  - An illustration of the tuberosity repair is depicted in Figures 22.6 and 22.7
  - We find it easier to pass these sutures prior to glenosphere implantation.
- Even in cases where there is comminution of the tuberosity, every effort should be made to include the comminuted fragments into the repair construct.
- The articular segment of the humeral head can then be removed and saved on the back table as this is an excellent source of bone graft.

Glenoid Preparation

- A posterior retractor is placed over the posterior rim of the glenoid, which retracts the humeral shaft and the tuberosity fragments posteriorly.
- A retractor placed over the anterior glenoid rim and along the inferior glenoid helps protect the axillary nerve while providing exposure of the glenoid.
- Using electrocautery, the entire labrum and proximal biceps anchor are removed.
- The anterior capsule often has to be released to provide adequate glenoid exposure.
- A central guide pin is placed aiming down the center of the glenoid vault.
- Positioning of the pin should be optimized such that the baseplate is positioned at the inferior most aspect of the glenoid to avoid scapular notching.
- The glenoid is then reamed, and the baseplate and glenosphere are positioned per manufacturer specifications.
  - Either a 36 or 39 mm glenosphere is typically used in these instances.
- We typically place a minimum of two locking screws into the baseplate with compression screws as well for adequate fixation

Humeral Preparation

- The arm is brought into an adducted and externally rotated position with the assistance of the hydraulic arm holder.
- The humerus is then reamed sequentially until an adequate rotational stability is appreciated.

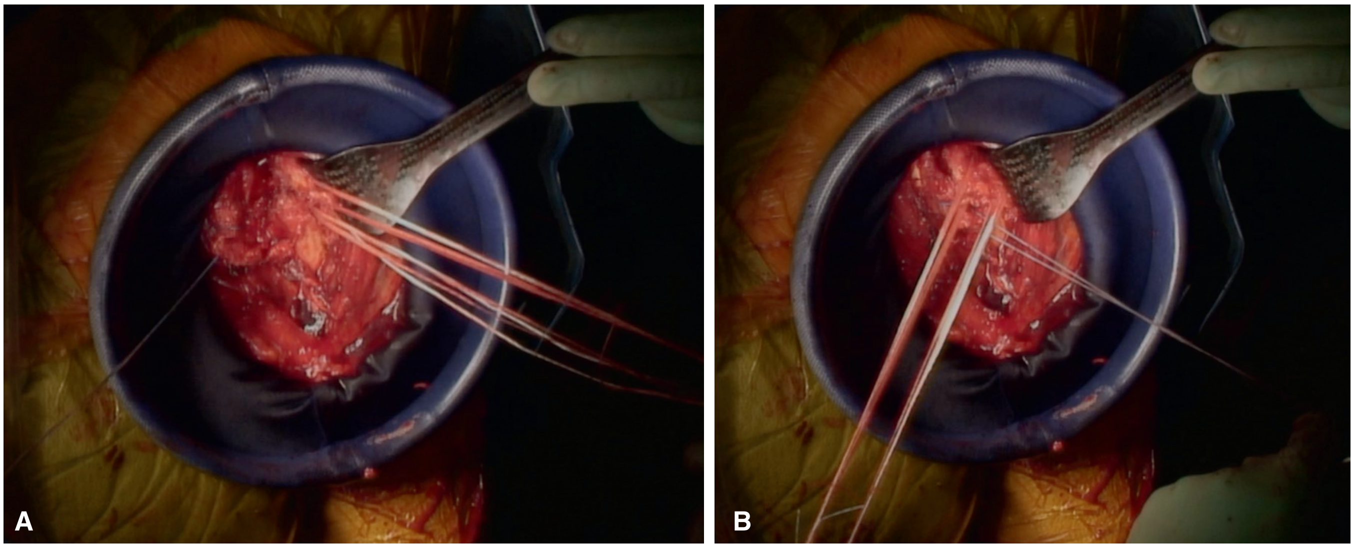

FIGURE 22.5 Sutures placed around the greater tuberosity and through the infraspinatus and teres minor (A). Reduction of the tuberosities (B).

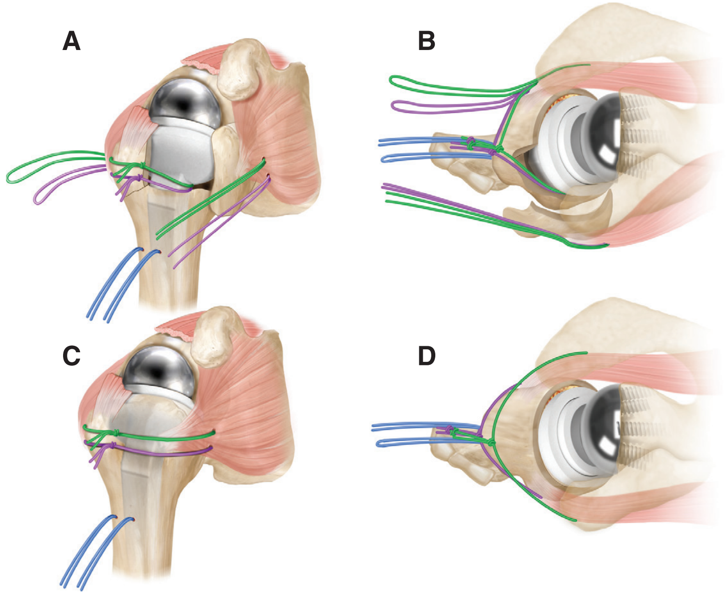

FIGURE 22.6 Four suture limbs are placed around the greater tuberosity (two green and two red) and two (one green and one red) are placed around the lesser tuberosity. Two of the suture limbs around the greater tuberosity are tied around the implant (A and B). The remaining two limbs from around the greater tuberosity are tied to those from the lesser tuberosity to provide horizontal fixation (C and D).

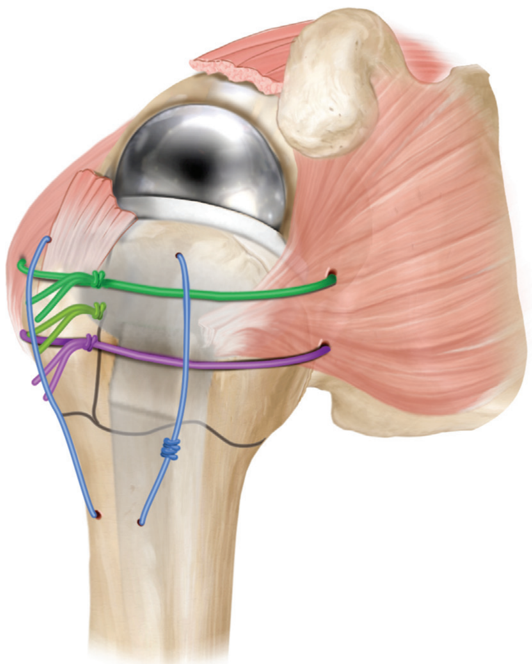

FIGURE 22.7 Lastly, the sutures placed just distal to the surgical neck (blue) are passed through the greater and lesser tuberosity to provide vertical fixation.

- We favor using a fracture stem without cement if adequate fixation can be achieved.
    - In most instances, the **fracture** is at the surgical neck, and cement needs to be used. A cement restrictor is placed based on depth of the stem.
- The humeral stem is positioned in approximately 20° of retroversion as assessed by the alignment rod on the humeral jig in relation to the patients forearm.
- Every effort should be made to restore anatomic humeral height as this is an important factor in avoiding instability.[45]
- In cases where the medial calcar is preserved, this can be a helpful landmark to help assess eventual implant height.
- We position the inferior medial aspect of the humeral socket such that it is directly above the medial calcar to help establish correct implant height.
- Use of the bicipital groove has been advocated by some authors to help guide appropriate retroversion; however, the groove becomes more anterior on the humerus as it progresses distally, which can lead to a stem placed in excessive amounts of retroversion.[11,46]
- A trial stem and liner is placed to assess simulated range of motion and soft-tissue tension with the tuberosities temporarily reduced using the traction sutures.
- Two drill holes are placed on either side of the bicipital groove approximately 1 cm distal to the surgical neck after the trial stem is removed, and two heavy nonabsorbable sutures are passed through each of these holes, which will eventually be used for vertical fixation of the tuberosities to the humeral shaft.

Humeral Stem Implantation and Tuberosity Fixation

- Autologous bone graft from the humeral head can be used to ensure a secure metaphyseal fit.
- Prior to the stem being impacted down to the appropriate height, two of the heavy nonabsorbable sutures

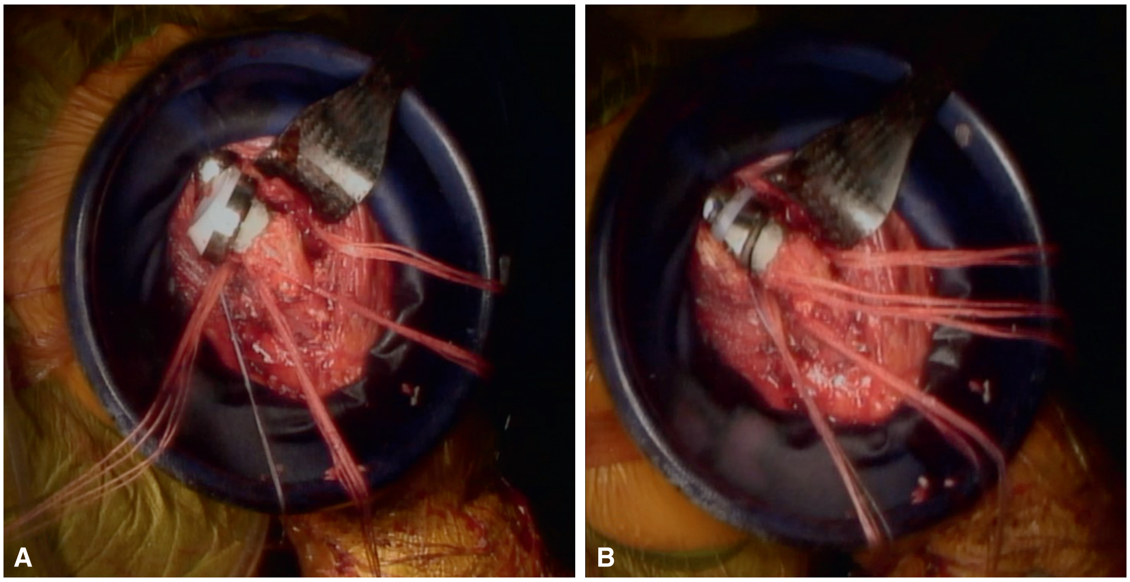

FIGURE 22.8 Humeral stem cemented into place with the sutures passed around the stem (A). Humeral prosthesis after being reduced to the glenosphere (B).

(two limbs from around the infraspinatus and two from around the teres minor) from around the greater tuberosity fragment are placed around the stem.

- Alternatively, some fracture stems have fins with suture holes, which allow the sutures to be placed through the humeral implant.
- The humeral stem is then impacted down to the appropriate height as determined previously based on the patients anatomy and soft-tissue tension (Figure 22.8).
- Two suture limbs around the greater tuberosity fragment (one from around the infraspinatus and one from around the teres minor) are then tied to the two corresponding suture limbs to bring the greater tuberosity back against the stem. Bone graft from the humeral head is packed here as well for aid in tuberosity healing.
- The two remaining suture limbs around the greater tuberosity fragment (one from around the infraspinatus and one from around the teres minor) are then taken through the subscapularis tendon lesser tuberosity interface in a modified Mason-Allen configuration and tied to the two corresponding suture limbs to bring the lesser tuberosity back against the stem. Again, bone graft from the humeral head is packed here as well for aid in tuberosity healing (Figure 22.9).
- The two previously placed suture limbs in the each hole of the humeral shaft are then placed through the infraspinatus and subscapularis to provide vertical stability to the construct. Therefore, one suture set from each hole is providing vertical stability to both the lesser and the greater tuberosity to the humeral shaft (Figure 22.10).

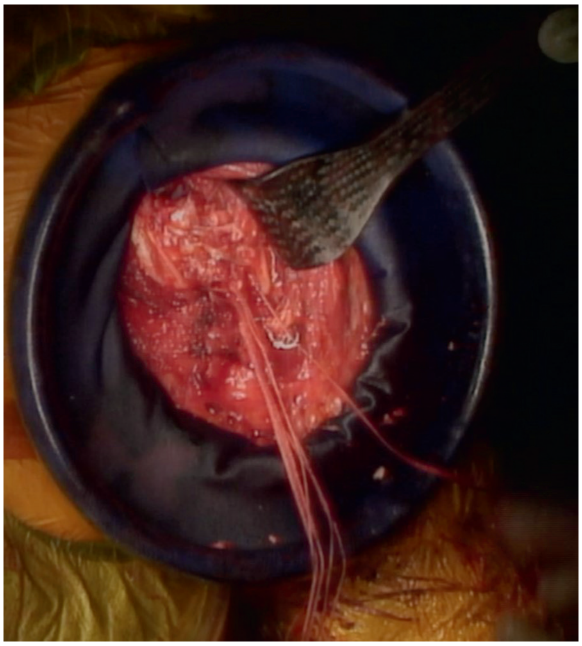

FIGURE 22.9 The horizontal limbs of suture around the greater and lesser tuberosities have been reduced and secured.

- Final tuberosity reduction and fixation is carefully evaluated (Figure 22.11).
- The wound is then copiously irrigated and closed in a layered fashion.
- We do not routinely use postoperative drains, even in the setting of **reverse shoulder arthroplasty** for **fracture**.

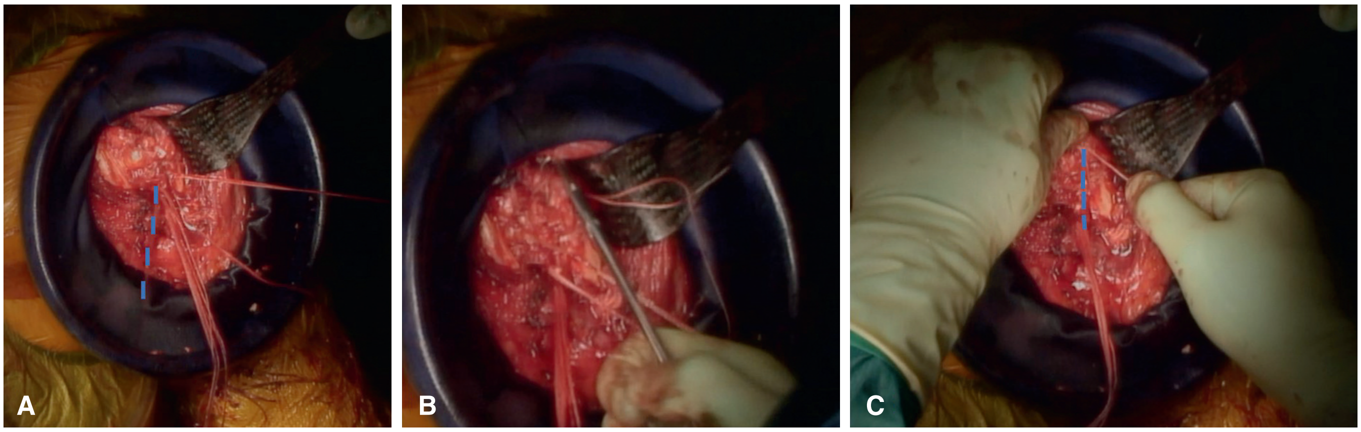

FIGURE 22.10 After the limbs of suture around the greater and lesser tuberosities have been secured to provide horizontal stability, the inferior suture limbs (blue dashed line) around the humeral shaft (A) are secured to the superior aspects of the tuberosities to provide vertical stability (B and C).

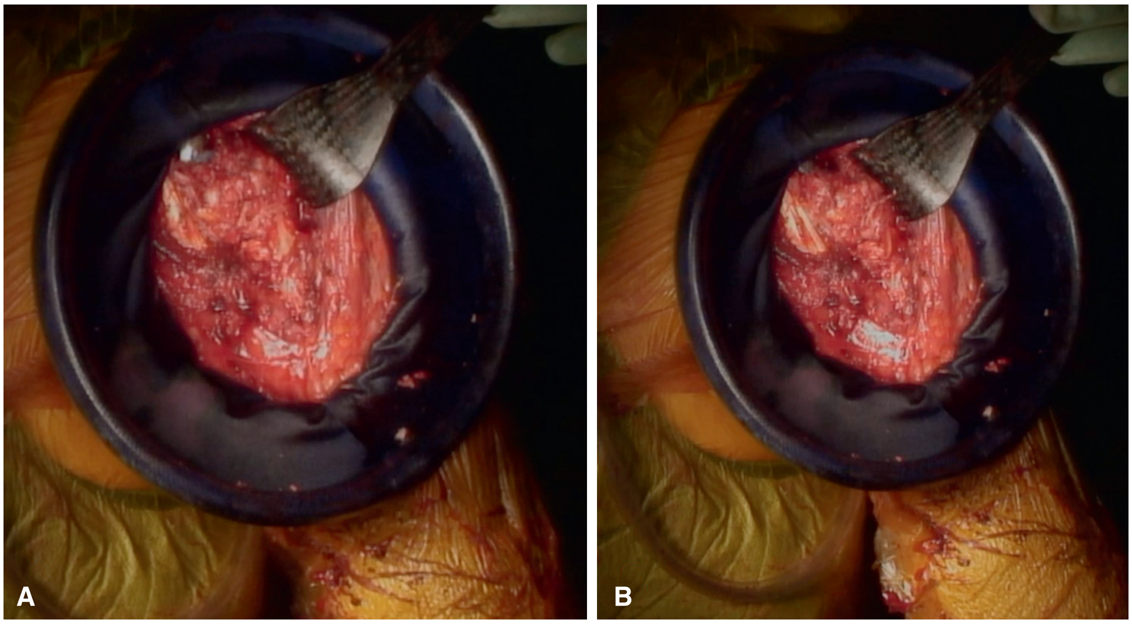

FIGURE 22.11 Final appearance of the **shoulder** in internal rotation (A) and external rotation (B) following **reverse shoulder arthroplasty** with anatomic tuberosity repair.

PEARLS

- **Reverse shoulder arthroplasty** for **fracture** can be a very successful operation in providing pain relief, excellent function, and restoring independence for many patients.
- Although tuberosity healing is not as essential for good outcomes when compared with **hemiarthroplasty**,[47-49] several studies have demonstrated functional outcomes, particularly with forward elevation and internal/external rotation of the arm, are significantly improved when the tuberosities heal.[50,51]
- Reestablishing humeral length and rotation are essential for optimizing prosthetic stability and functional outcome (Figure 22.12).[45]
  - Using the medial calcar is a helpful reference point to ensure proper height.

PITFALLS

- ✖ In highly comminuted **fractures**, it can become difficult to restore native height and version.
  - Failing to do so will lead to altered soft-tissue tension and may lead to prosthetic impingement.
  - Malposition of the humeral component coupled with altered soft-tissue tension may lead to instability of the **shoulder**.
  - Over tensioning the soft tissue either out of concern for instability or secondary to component malposition can lead to acromial stress **fractures**, particularly in elderly patients with poor bone quality.

FIGURE 22.12 Postoperative radiograph of the proximal humerus fracture previously depicted following reverse shoulder arthroplasty.

Hemiarthroplasty

Please refer to the previous section and the Surgical Management section on **Hemiarthroplasty** for additional details.

PEARLS

- The success of a **hemiarthroplasty** in the setting of **proximal humerus fracture** is intimately related to the ability to anatomically reduce the tuberosities and reestablish anatomic height and version.
- Numerous methods can provide a template for the specific anatomy of the patient.
- Intraoperative use of fluoroscopy can also be used to help ensure anatomic reduction.
- Additionally, using the "best-fit" circle method as described by Alolabi and colleagues[38] can help avoid overstuffing the joint.

PITFALLS

- Failing to reestablish anatomic height and version will lead to inaccurate reduction and tensioning of the tuberosities and increases the likelihood of failure.[39]
- Overstuffing the joint by not accurately matching humeral head anatomy will lead to excessive tension on the tuberosities and may lead to compromised rotator cuff function down the road.

POSTOPERATIVE MANAGEMENT

- Following either **reverse shoulder arthroplasty** or **hemiarthroplasty** performed for **fracture**, the patient is immobilized in an abduction sling.
- We tend to favor the abduction sling as it takes tension off the deltoid and the repaired tuberosities.
- The patient is encouraged to work on active motion of the wrist and hand and passive motion of the elbow several times a day to avoid stiffness and for edema management.
- The patient is kept in the **shoulder** sling for 6 weeks, and the sling is then gradually removed and the patient started on physical therapy.
- Patient progresses through a program of passive range of motion followed by active-assist motion and then active range of motion.
  - Strengthening is not initiated until roughly the 12 week time point.
- After **reverse shoulder arthroplasty**, the patient has a 15 pound lifting restriction for life.

Outcomes

Hemiarthroplasty

- Inconsistent and unpredictable outcomes following **hemiarthroplasty** for **fracture** are largely secondary to the status of the tuberosities.
  - In order to get the tuberosities to heal, anatomic restoration of the humeral height and version is necessary, which can often be challenging in the posttraumatic setting.
- If the tuberosities fail to heal or resorb (Figure 22.13), the patient is essentially left with a rotator cuff–deficient **shoulder**. This often results in high rates of dissatisfaction following **hemiarthroplasty** for **fracture**.[39,43,52,53]
- Despite the unpredictable and sometimes poor functional outcomes, **hemiarthroplasty** does reliably result in minimal pain.[29,52,54]
- Kontakis et al[52] published a systematic review consisting of 16 studies and a total of 810 hemiarthroplasties performed for **proximal humerus fracture**.
  - Unsatisfactory results were seen in 41.6% of patients.
  - The mean constant score was only 56.6 and mean range of motion was limited to 105.7° (10°-180°) of forward flexion and 92.4° (15°-170°) of abduction.[52]
- Several authors have reported outcomes, which highlight the dependence on tuberosity healing.[29,39,53,55]
- Mighell and colleagues[43] reported that patient satisfaction and function were very dependent on the position and healing rates of the tuberosities.
  - Head to tuberosity distance less than 20 mm resulted in significantly improved motion and functional outcomes compared with that when the head to tuberosity distance was greater than 20 mm.
- Smith et al[55] reported that half of the complications following **hemiarthroplasty** were secondary to malreduction or healing of the tuberosities.

FIGURE 22.13 Postoperative radiograph of a **hemiarthroplasty** performed for a **proximal humerus fracture**, demonstrating resorption of the greater tuberosity.

- Boileau et al[39] reported on 66 patients following **hemiarthroplasty** for **fracture** and noted tuberosity malposition in 50% of patients, which correlated with unsatisfactory outcomes.
- Antuna and colleagues[53] reported unsatisfactory outcomes in 53% of patients with a minimum of 5 years follow-up following **hemiarthroplasty**.
- A few prospective studies have compared **hemiarthroplasty** with nonoperative management of **proximal humerus fractures**.
  - Olerud et al[56] evaluated 55 patients with displaced four-part **fractures** randomized to either **hemiarthroplasty** or nonoperative treatment.
    - The patients had a mean age of 77 years (range, 55-92) and 86% of patients were female.
      - The authors reported that a health-related quality of life measure (HRQoL) was significantly better in patients treated with **hemiarthroplasty**; however, there were no significant differences in DASH or VAS scores between the groups.
  - Boons and colleagues[57] randomized patients older than the age of 65 years with four-part **fractures** to **hemiarthroplasty** or nonoperative treatment.
    - The authors reported no significant differences in constant score and simple shoulder test between the groups.

Reverse Shoulder Arthroplasty

- **Reverse shoulder arthroplasty** represents an attractive option for older, low-demand patients with **proximal humerus fractures** because of its ability to utilize the large lever arm of the deltoid irrespective of the integrity of the rotator cuff.
- The reliance on the deltoid likely puts less force on the healing tuberosities following **fracture** and may contribute to the higher rates of tuberosity healing following **reverse shoulder arthroplasty** compared with **hemiarthroplasty** for **fracture**.
- Although tuberosity healing is not essential for good functional outcomes following **reverse shoulder arthroplasty**, better outcomes have been reported when the tuberosities heal.[50,51]
  - Gallinet et al[51] performed a retrospective review of 41 patients treated with **reverse shoulder arthroplasty** for **fracture**.
    - The tuberosities were repaired in 27 patients and completely excised in 14 patients.
    - Patients with healed tuberosities had significantly better forward flexion, external rotation with the arm at the side and at 90° of abduction, DASH and constant scores compared with those when there was no tuberosity healing.
  - Bufquin et al[58] reported satisfactory functional outcomes despite migration of the tuberosities in 43 consecutive patients with three- or four-part **fractures** treated with **reverse shoulder arthroplasty**.
- **Reverse shoulder arthroplasty** when performed for **fracture** also results in more predictable postoperative motion.
  - Lenzarz et al[59] reported on 30 patients with a mean age of 77°years treated with **reverse shoulder arthroplasty** for three- and four-part **fractures**.
    - Postoperative mean active forward flexion was 139° and mean active external rotation was 27°.
  - Klein and colleagues[60] demonstrated a mean postoperative forward flexion of 123° and mean abduction of 113°.

Reverse Shoulder Arthroplasty Versus Hemiarthroplasty

- Studies that have compared **hemiarthroplasty** with **reverse shoulder arthroplasty** for the treatment of **proximal humerus fractures** have generally favored **reverse shoulder arthroplasty**.[47-49,61-65]
  - Two recent meta-analyses have demonstrated more favorable outcomes with **reverse shoulder arthroplasty** over **hemiarthroplasty**.[47,61]
    - Wang and colleagues[61] evaluated eight studies consisting of 421 hemiarthroplasties and 160 **reverse shoulder arthroplasties**.
      - Overall, **reverse shoulder arthroplasty** had lower complications (8.5% vs 22.2%), higher ASES scores, higher rate of tuberosity healing (83.7% vs 47.1%), and improved forward elevation (128.8° vs 95.3°) compared with that of **hemiarthroplasty**.
    - Gallinet et al[47] analyzed a total of 22 studies in their review, which also demonstrated significantly

better constant score and postoperative range of motion with **reverse shoulder arthroplasty**.
        - Rates of tuberosity healing were not influenced by **reverse shoulder arthroplasty**; however increasing age seemed to adversely influence tuberosity healing following **hemiarthroplasty**.[47]
- Cuff and colleagues[49] evaluated 53 consecutive patients with three- or four-part **fractures** treated with either **hemiarthroplasty** or **reverse shoulder arthroplasty**.
    - **Reverse shoulder arthroplasty** resulted in significantly better outcomes regarding: forward flexion (139° vs 100°), ASES score (77 vs 62), SST (7.4 vs 5.8), and patient satisfaction (91% vs 61%).
    - 91% of patients treated with **reverse shoulder arthroplasty** had healed tuberosities compared with that of only 61% with **hemiarthroplasty**.
        - Importantly, among the patients treated with **hemiarthroplasty** where the tuberosities did not heal, no patient had forward elevation greater than 90°.
        - For comparison, even among the patients treated with **reverse shoulder arthroplasty** where the tuberosities did not heal, mean forward flexion was still 132°.
- Sebastia-Forcada et al[48] prospectively evaluated 62 patients older than the age of 70 years randomized to treatment with either **reverse shoulder arthroplasty** or **hemiarthroplasty** for **fracture**.
    - Patients treated with **reverse shoulder arthroplasty** had significantly better mean University of California-Los Angeles (29.1 vs 21.1) and constant (56.1 vs 40.0) scores, forward elevation (120.3° vs 79.8°), and abduction (112.9° vs 78.7°).
    - 56.6% of the patients treated with **hemiarthroplasty** had healing of their tuberosities and these patients had significantly worse functional outcomes.
    - Only 64.5% of patients treated with **reverse shoulder arthroplasty** had healing of their tuberosities; however, the authors reported that functional outcome was irrespective of tuberosity healing.[48]
- Chalmers et al[64] reported an apparent economic benefit to **reverse shoulder arthroplasty** for **fracture** as well.

COMPLICATIONS

- The most concerning complication following **hemiarthroplasty** is nonunion or malunion of the tuberosities.
- Without tuberosity healing, the patient is essentially left with a deficient rotator cuff, resulting in poor functional outcomes and high rates of dissatisfaction.
    - A number of these patients will demonstrate progressive superior migration of the humerus, which can become painful and necessitate revision to **reverse shoulder arthroplasty**.[39,43,53]
    - Patients with failed hemiarthroplasties who have to get converted to **reverse shoulder arthroplasty** do not perform as well as those with primary **reverse shoulder arthroplasties**.[66,67]
- Instability following **reverse shoulder arthroplasty** is often the most concerning postoperative complication, which ranges from approximately 4% to 5%.[68,69]
    - Malposition of the humeral component leading to altered soft-tissue tension or prosthetic impingement can lead to instability.
    - In the posttraumatic setting, this is often more challenging than when performing **arthroplasty** for arthritis or rotator cuff deficiency.
    - Most modern **arthroplasty** systems have several options to adjust the soft-tissue tension to help avoid instability following reverse **arthroplasty**.
    - It is important to use a system, which allows revision from a **hemiarthroplasty** to a reverse total **shoulder arthroplasty** with the same humeral stem platform.

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