Management of Proximal Humerus Fractures in Adults

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Proximal humerus fractures are the third most common fracture type in adults, with their incidence increasing over time. There are varied approaches to both the classification and treatment of proximal humerus fractures. Optimal treatments for this fracture type are still widely open to debate.

proximal humerus fracture management

1. Epidemiology

Proximal humerus fractures represent 5–6% of all fractures [1][2]. It is the third most common fracture in older adults [3]. The incidence of proximal humeral fractures varies by region. An analysis in southern Europe showed an incidence rate of 60.1 proximal humeral fractures per 100,000 person-years from 2016 to 2018 [4]. In Australia, the incidence of proximal humeral fractures was found to be 45.7 fractures per 100,000 person-years in 2017 [5].

Females sustain higher rates of proximal humeral fractures than males [1][4][5]. In the southern Europe analysis, the female incidence rate of proximal humeral fracture was 89.3 per 100,000 person-years as compared to 28.2 in men [4]. In Australia, women over 85 years old had the highest proximal humeral fracture incidence at 711.8 fractures per 100,000 person years in 2017 [5]. Typically proximal humerus fractures occur in a bimodal distribution pattern; high energy injuries in young individuals and low energy injuries in elderly individuals with osteoporotic bone [1].

Proximal humeral fracture incidence is also increasing over time. In Australia, proximal humeral fracture incidence rose from 28.5 per 100,000 in 2008 to its 2017 rate of 45.7 per 100,000 [5]. This increasing trend has been occurring for the last several decades, with the population-adjusted incidence rate in New York City rising from 15.35 per 100,000 in 1990 to 19.4 per 10,000 in 2010 [6]. The increasing trend in PHF incidence is most likely due to the increasing median age of the population in these studies (Khatib et al., 6th citation below).

2. Surgical Approach

2.1. Patient Positioning

Percutaneous fixation can be performed with the patient positioned in either the supine or beach-chair position. Care should be taken to position fluoroscopy to allow for complete visualization of the proximal humerus in two orthogonal views.

2.2. Fracture Reduction

The ability to obtain an anatomic reduction closed is the key to minimally invasive percutaneous techniques. Understanding the deforming forces on the fracture fragments and utilizing reduction maneuvers that counteract the deforming forces can help achieve an anatomic closed reduction. Deforming forces on the fracture fragments are specific to each fracture pattern, thus fracture-specific reduction maneuvers have been previously described [7].

2.2.1. Two-Part Greater and Lesser Tuberosity Fracture

Percutaneous fixation is appropriate for mobile greater tuberosity fractures with minimal displacement. Placement of a percutaneous pin into the tuberosity to act as a joystick, followed by rotation of the humerus, can help reduce the tuberosity. Once reduced, a second pin can be driven through the tuberosity across the fracture site for definitive fixation. Alternatively, a mini-open reduction through a small 2 to 3 cm incision distal to the anterolateral acromion with a deltoid split can be utilized to introduce a reduction pick or bone tamp to assist with tuberosity reduction and fixation. Lesser tuberosity fractures are rarely fixed percutaneously as it can be difficult to obtain an acceptable closed reduction and there is danger of injuring the axillary nerve and anterior humeral circumflex vessels [7].

2.2.2. Two-Part Surgical Neck Fractures

The two major fracture fragments in a two-part surgical neck fracture are the humeral head and the humeral shaft. Typically, the humeral head remains in neutral because all of the rotator cuff attachments to the head fragment are intact. While the pectoralis major muscle displaces the humeral shaft fragment anteromedially and internally rotates it. The pectoralis major is the primary deforming force, and its effects can be minimized by flexing, adducting, and internally rotating the humerus. Traction can then be applied to the arm with a posteriorly directed in order to reduce the apex anterior angulation. Once reduced, the humeral shaft can be externally rotated to the neutral position.

2.2.3. Three-Part Greater Tuberosity Fractures

Similar to two-part surgical neck fractures, the humeral shaft will assume a position of anteromedial displacement and internal rotation secondary to the pull of the pectoralis major. The unopposed pull of the subscapularis on the intact lesser tuberosity internally rotates the head fragment. Reduction of the surgical neck is performed as described above. The surgical neck portion of the fracture is then percutaneously fixed to the humeral shaft. Following fixation, the arm can be positioned in slight external rotation to counteract the pull of the rotator cuff muscles on the greater tuberosity. The tuberosity can then be reduced using either a k-wire or bone hook and fixed with cannulated screws or antegrade pins.

2.2.4. Three-Part Lesser Tuberosity Fracture

Again, the humeral shaft is displaced anteromedially with slight internal rotation secondary to the pectoralis major; while the humeral head is abducted and externally rotated, with apex-anterior angulation due to the unopposed pull of the rotator cuff on the greater tuberosity. Reduction of the surgical neck can be achieved by flexing and externally rotating the arm. While traction and a postero-medially directed force help reduced the humeral shaft to the head component. Often a closed reduction cannot be achieved and a small incision must be made to improve exposure of the fracture fragments. Internal rotation of the arm and Kirschner wires used as joysticks can aid in reduction of the lesser tuberosity.

2.2.5. Four-Part Valgus-Impacted Fracture

In order to obtain an anatomic reduction of a four-part valgus-impacted fracture pattern, the lateral aspect of the humeral head must be elevated. A 2 to 3 cm incision can be made 2 cm distal to the anterolateral acromion to aid with reduction attempts. Typically, a small bone tamp or periosteal elevator can be inserted through the tuberosity defect to engage the lateral aspect of the humeral head and used to disimpact the articular surface from the shaft. The goal of the reduction is to elevate the lateral aspect of the articular surface utilizing the intact medial periosteum as a hinge. Once elevated the head can be percutaneously fixed in that position and then the shaft can be reduced to the head fragment as described above.

2.3. Fracture Fixation

Fixation of the humeral shaft to the head is typically performed with 2.5-mm Schantz pins placed in a retrograde fashion from the shaft into the humeral head. Care should be taken to place the pins on the lateral cortex in a safe zone that avoids injury to both the axillary and radial nerves. If the pins are kept above the deltoid insertion, the radial nerve is typically protected. While the axillary nerve is, on average, located 5 cm distal to the acromion [8]. A soft tissue sleeve should be utilized when placing pins through the deltoid to decrease the risk of neurovascular injury. Average humeral retroversion is 19 degrees, thus percutaneous pins should be directed posteromedially to account for this angle [9]. Pins placed from anterior to posterior place the musculocutaneous nerve and biceps tendon at risk and should be avoided if possible.

After fixing the humeral head to the shaft, the tuberosities can be addressed. Cannulated screw and pin fixation have been described for fixation of the tuberosities [10][11]. Under fluoroscopic guidance cannulated screws or pins are typically placed from proximal lateral to distal medial [12]. In order to reduce the risk of pin migration, terminal threads can be utilized to secure pins in place. Care should be taken to advance pins to engage dense subchondral bone. Some authors routinely bend pins beneath the skin to act as a mechanical block to backing out, however migration may still occur.

2.4. Postoperative Management

Typically, the operative extremity is immobilized in a sling for the first two weeks postoperatively. Immediate active elbow, wrist, and hand range of motion is permitted. Pendulum exercises can be started immediately, if fixation is thought to be stable enough to tolerate. Pins are removed at 4 to 6 weeks postoperatively when there is radiographic evidence of healing. Plain films should be obtained weekly to ensure that fracture reduction is maintained and pin migration has not occurred. Following pin removal, active-assisted range of motion can be initiated followed by strengthening exercises at 12 weeks postoperatively.

2.5. Complications

Pin migration is a common complication following CRPP of proximal humerus fractures with potentially devastating complications [13]. Previous studies have demonstrated that threaded pins placed into the proximal humerus can migrate and cause neurovascular injury to major vascular or intra thoracic structures [13][14]. Close follow-up of these patients is mandatory and pins should be removed if there is any radiographic evidence of loosening.

There is an increased risk of infection if pins are left protruding through the skin. Superficial infections are typically treated with pin removal, local wound care, and oral antibiotics. However, deeper infections, though less common, can lead to significant complications including osteomyelitis [7].

Reported union rates following CRPP of proximal humerus fractures are high, likely secondary to minimal soft tissue dissection and devascularization. Loss of reduction and malunion more commonly occur than nonunion [7]. Varus angulation of the articular surface and posterosuperior displacement of the greater tuberosity are the most common malunions, which can lead to subacromial impingement, pain, and loss of function [7]. There is a higher risk of early pin loosening and loss of fixation in patients with osteoporosis and increased age.

The risk of avascular necrosis (AVN) is largely determined by the injury pattern itself [15]. The results of Kralinger et al. suggest that the rate of AVN was lower in patients treated with CRPP when compared with ORIF [16]. However, the findings of Kralinger et al. may be the result of selection bias as more severe fracture patterns, which have an increased risk of AVN, are more commonly treated with ORIF. Development of AVN following CRPP of proximal humerus fractures has been previously reported [7]. AVN may take up to 2 years following injury to develop and patients should be followed at regular intervals for that length of time.

Neurovascular injury is uncommon during CRPP of proximal humerus fractures [7]. In cadaveric studies investigating percutaneous pinning of the proximal humerus, injuries to the axillary nerve [17], cephalic vein, and biceps tendon [12] were noted. The results of the studies suggest that neurovascular structures are at risk during CRPP and thorough anatomical knowledge is mandatory.

2.6. Outcomes

The results of proximal humerus fracture CRPP have been favorable. Jaberg et al. showed that, for 48 CRPP patients included with an average of 3 years of follow up, 70% achieved a good or excellent result [18]. Similarly, Fenichel et al. reported 70% good or excellent results and an average constant score of 81 (scale 0–100) in 56 patients treated with CRPP [19]. Likewise, Keener et al. reported good or excellent outcomes for 27 proximal humerus fractures treated with CRPP, with an average of 35 months of follow up [11]. In a cohort of 27 patients, Resch et al. reported a mean constant score of 91 for three-part fractures and 87 for four-part fractures fixed with CRPP [10].

3. Open Reduction and Internal Fixation

Patients with proximal humeral fracture patterns that may benefit from operative fixation but do not meet criteria for closed reduction percutaneous are candidates for open reduction internal fixation. Patients with un-reconstructable head splitting fractures, fractures devoid of all soft tissue attachments [20], severe valgus impacted fractures with disruption of the medial periosteal hinge [15][20][21], and displaced multi-part fractures with delayed presentation may benefit from primary arthroplasty [22].

4. Surgical Approach

4.1. Patient Positioning

For operative fixation patients are typically positioned in the beachchair or supine position. The patient should be positioned with the head immobilized and the shoulder corner pushed away from the operative side in order to enable C-arm fluoroscopy access from the opposite side of the table.

4.2. Surgical Technique

Traditionally the deltopectoral approach has been the most widely utilized approach for fixation of proximal humerus fractures. The deltoid-split is an alternative approach that offers improved access proximally to the tuberosities and articular surface for reconstruction. During a deltopectoral approach the surgeon can improve visualization of a retracted tuberosity fragment by passing heavy stay sutures through the rotator cuff and drawing it anteriorly.

There is increased risk of intraoperative axillary nerve injury or late deltoid insertion pull off with the deltoid-split approach [23]. It also relies on indirect visualization of the fracture reduction especially at the medial calcar. When performing a deltoid-split approach a 5 cm longitudinal incision is made in line with the arm along the posterior border of the clavicle. The deltoid is split bluntly at the raphe between the anterior and middle thirds of the deltoid producing an upper “window” exposing the entire proximal humerus. Next care is taken to identify the anterior terminal branch of the axillary nerve and its accompanying vessels. After protecting the neurovascular bundle, the split can be extended distally to produce a lower “window” exposing the proximal portion of the humeral diaphysis. Axillary nerve injuries and injuries to the deltoid insertion have been reported but are uncommon in clinical practice [20][24][25][26][27]. Compared with the deltopectoral approach, the deltoid split approach offers better access to the greater tuberosity and posterior fracture patterns, as well as the lateral aspect of the humerus for plating [25][26]. The deltoid split approach can also be very useful in valgus impacted proximal humerus fractures where the lesser tuberosity is greatly displaced.

4.3. Fracture Reduction

The goal of operative fixation is to achieve an anatomic reduction of the key fracture fragments. Fracture reduction should be performed in a logical sequence. If the humeral head is dislocated it should be reduced first under direct visualization. The surgeon can gain access to the empty glenoid through a rotator interval arthrotomy. In anterior fracture dislocations the humeral head is typically engaged on the anterior glenoid rim, and on the posterior glenoid rim in posterior fracture dislocations. The surgeon must first disimpact the humeral head from the glenoid; this can be performed with a periosteal elevator or osteotome. Following dis-impaction the glenohumeral joint should then be reduced and the articular surface can be pinned after achieving acceptable alignment and angulation. At this point bone grafting procedures may be performed if indicated. The surgeon then can choose to either reduce the tuberosities to the head anatomically or reduce the head to the proximal shaft. In order to help facilitate reduction of the tuberosities heavy stay sutures may be passed through the bone-tendon interface to help with tuberosity manipulation. Several technical tricks may help the surgeon achieve an anatomic reduction: Kirschner wires can be inserted into fracture fragments and used as joysticks to manipulate the fragments, unicortical plates can be used as a preliminary reduction tool, a bump in the axilla can help lateralize a medially displaced shaft, and you can even pin the head to the glenoid.

Often displaced proximal humeral fractures are unstable following reduction due to poor bone quality and comminuted fracture patterns. Adjuvant techniques can be helpful to improve construct stability and prevent early displacement. Typically the cancellous proximal humeral metaphyseal bone is impacted in three- and four-part fractures [20][28]. These defects can be filled with morselized autograft or with allograft [22][29][30]. Posteromedial calcar comminution of the surgical neck is frequently encountered in displaced surgical neck fractures with varus angulation [31]. Several studies have highlighted posteromedial calcar comminution as a risk factor for varus collapse of the surgical neck as a result of posteromedial instability [22][27][32][33][34]. The use of a locking plate in which screws are inserted along the calcar in a low position within the head to buttress the area of comminution, or a fibular strut graft have been shown to be helpful in restoring stability of fractures with calcar comminution [22][27][34]. The fibular strut graft helps restore stability by bridging across the area of comminution and substitutes for the compromised posteromedial buttress. In an elderly patient with severe comminution it can occasionally be appropriate to impact the shaft within the head to help restore stability by producing “bayonet” apposition of the shaft within the head fragment [22]. Heavy stay sutures through the tuberosities can be passed through eyelets in the plate, which creates a tension-band construct that counterbalances the deforming forces of the rotator cuff.

4.4. Fracture Fixation

The plate should be positioned on the lateral aspect of the proximal humerus posterior to the bicipital groove, in order to prevent damage to the long head of biceps and arcuate artery, and it must also be caudal to the cranial-most aspect of the greater tuberosity to avoid subacromial impingement. The subchondral bone beneath the articular surface is predictably dense, however bone mineral density does progressively decreases towards the center of the humeral head and extending distally into the metaphysis [35]. The surgeon should attempt to place screws in the calcar and inferior aspect of the humeral head when possible as the anterosuperior quadrant has the weakest bone [23][36][37]. The medial calcar screws are the most important screws in the construct and should drive the cranial/caudal plate positioning. In order to avoid joint penetration screws should be placed 5 to 10 mm from the articular surface [22].

4.5. Postoperative Management

Postoperative rehabilitation regimens vary between surgeons but typically follow the same general principles. Patients are immobilized 2–4 weeks postoperatively depending on the stability of fracture fixation. Immediate active elbow, wrist, and hand range of motion is permitted. Pendulum exercises can be started immediately. Gradually passive shoulder range-of-motion exercises are introduced following sling removal. Active-assisted range of motion can be initiated followed by strengthening exercises at 12 weeks postoperatively.

5. Open Reduction Internal Fixation with an Intramedullary Nail

Historically intramedullary nails (IMN) were uncommonly utilized for fixation of proximal humerus fractures due to concerns regarding rotator cuff morbidity, iatrogenic fracture, and proximal screw migrations [38]. However modern nails include improved locking mechanisms for the proximal screws with fragment specific fixation as well as a straight geometry that allows for insertion of the nail medial to the insertion of the rotator cuff. These improved IMN designs has led to a resurgence of interest in utilizing these implants for fixation of proximal humerus fractures [39]. Intramedullary nails may hold advantages over proximal locking humerus plates in select patients with proximal humeral fractures including a smaller approach with less risk of blood loss.

6. Surgical Approach for ORIF with an Intramedullary Nail

6.1. Patient Positioning

The patient should be placed in the same position as discussed above in ORIF.

6.2. Surgical Technique

There are several described techniques for the approach to intramedullary nailing of proximal humerus fracture. For the researchers preferred technique a small incision is made in line with the anterior border of the acromion extending distally. The raphae between the middle and anterior thirds of the deltoid are split bluntly to access the subdeltoid space. A limited bursectomy can be performed to expose the insertion of the rotator cuff on the greater tuberosity. The rotator cuff tendon should be inspected for any associated tearing. Often a traction stitch through the rotator cuff musculotendinous junction can be utilized to help mobilize the head fragment and expose the supraspinatus muscle bed. Care is then taken to make a longitudinal incision through the supraspinatus muscle exposing the articular margin of the humeral head, which is the insertion point for a straight humeral IMN. The long head of the biceps tendon is routinely encountered anterior to the start point for the IMN and should be protect. In contrast, the appropriate start point for a curved IMN is more lateral, which can potentially violate the tendinous insertion of the rotator cuff on the greater tuberosity.

6.3. Fracture Reduction

Reduction can be obtained through the various closed reduction techniques discussed above. Again, a traction stitch through the supraspinatus tendon can be helpful in correcting humeral head varus. Kirschner wires can be inserted into fragments and used as joysticks to aid with reduction.

6.4. Fracture Fixation

In order to access the start point for a humeral IMN, the arm must be positioned in slight extension and adduction. Once the reduction is confirmed on fluoroscopy, a guide pin is inserted in line with the axis of the humeral shaft. Every system has its particular technique but all require a correctly placed guide wire followed by a reamer or a handheld awl to create a proximal opening for passing the nail. Longer nails may require diaphyseal reaming over a longer guidewire. The humeral IMN is then inserted under fluoroscopy and care is taken to prevent iatrogenic fracture. The proximal end of the humeral IMN must be placed at least 5 mm beneath the cortex of the humeral head; no protrusion of the nail can be tolerated. In order to lock the nail with the correct trajectory, the aiming arm should be rotated anteriorly approximately 25 degrees to match the retroverted axis of the humeral head. Unicortical locking screws are then placed in the proximal portion of the nail to prevent intra-articular penetration, and bicortical distal locking screws are placed distally. After confirming fracture reduction and nail position, continuous fluoroscopy should be utilized while rotating the arm to confirm that no proximal screws penetrate the glenohumeral joint. Rotator cuff tears can then be repaired with transosseous sutures or suture anchors through the incision. The supraspinatus muscle fibers should be repaired side-to-side as well as the deltoid raphae.

6.5. Postoperative Management

Patients are typically immobilized for 6 weeks postoperatively in an abduction pillow sling. Immediate active elbow, wrist, and hand range of motion is permitted as well as passive shoulder ROM. Pendulum exercises can be started immediately. Active-assisted and full active range of motion exercises can begin 4–6 weeks after fixation depending on fracture morphology, with strengthening exercises beginning at approximately 12 weeks postoperatively.

6.6. Complications

The most common complications of open reduction and internal fixation of proximal humeral fractures are post-traumatic arthrofibrosis, nonunion, malunion, osteonecrosis, early fixation failure, and infection.

Post-traumatic arthrofibrosis following ORIF of proximal humeral fractures has a good prognosis if the fracture heals. Clinically patients present similar to primary adhesive capsulitis with painful loss of passive shoulder range of motion [40]. The majority of patients will typically respond to physical therapy. If there is a plateau in recovery at 6 months post op then manipulation under anesthesia may be required. If manipulation fails to restore acceptable range of motion, then, under the same anesthesia event, arthroscopic rotator interval and capsular release should be performed [22][41]. There is increased risk of peri-implant fracture during manipulation under anesthesia, thus care should be taken to avoid this complication.

Nonunion can occur secondary to a mechanically unstable fracture reduction and fixation or as a consequence of poor surgical technique. Patients often presents with pain, decreased range of motion, and loss of function with plain films that confirm bone resorption and lack of healing. Revision ORIF is usually not feasible and revision to an arthroplasty is recommended if symptoms are debilitating [22]. In contrast, malunion is generally well tolerated in elderly patients with limited functional demands. However, younger patients can develop debilitating symptoms from malunion causing poor shoulder function, subacromial impingement, and tear of the rotator cuff. Corrective osteotomies or conversion to arthroplasty can be considered for young patients with severe symptom secondary to malunion.

Osteonecrosis has been reported in up to 15% of patients following ORIF for proximal humeral fractures [22]. Fracture dislocations and displaced multipart fractures are at higher risk of osteonecrosis secondary to disruption of the humeral head end arterial blood supply [15][20][22][24]. Osteonecrosis can also occur secondary to poor surgical technique with excessive soft tissue stripping. Patients clinical presentation should be the major determinant in therapeutic decision making. Some Patients may present postoperatively with radiographic evidence of osteonecrosis and minimal symptoms, and these people are likely tobe amenable to nonoperative treatment [42]. However, the majority of patients with proximal humeral osteonecrosis will develop symptomatic advanced collapse [43]. Conversion to arthroplasty should be considered for patients with severe symptoms and advanced collapse.

Infection is relatively uncommon following proximal humeral ORIF secondary to rich vascularity and good soft tissue coverage [22]. Superficial infections typically resolve with oral antibiotic therapy. Deep infections with stable hardware should be treated with incision and debridement, preservation of fixation, and antibiotic therapy. If the infection is refractory to hardware retention and prolonged antibiotic therapy, then a more radical debridement with implant removal should be performed with delayed reconstruction.

6.7. Outcomes

Gomberwalla et al. performed a meta-analysis on data from 12 studies comparing open reduction and internal fixation of proximal humerus fractures to arthroplasty for treatment of 3- and 4-part fracture patterns. Open reduction internal fixation demonstrated significantly higher constant scores than arthroplasty [44]. However, the studies included exhibited significant heterogeneity limiting the study’s conclusions. Constant scores were observed to decreased significantly with severity of fracture, increasing age, and osteonecrosis [44].

Mayr et al. randomized patients presenting with a proximal humeral fracture to fixation with either an intramedullary nail or a locking plate. At 12 months follow up, the authors found no significant difference in pain, range of motion, or overall complication rate [45]. There was no difference in functional outcome assessed by the Constant score, however DASH scores were slightly lower in the intramedullary nail group at 12 months [45]. Loss of reduction and screw cut out was significantly lower in the intramedullary nail group [45]. When comparing straight to curvilinear intramedullary nails Lopiz et al. demonstrated no difference in Constant score between the constructs [46].

However, straight IMN demonstrated significantly lower incidence of rotator cuff dysfunction and incidence of screw loosening [46].

7. Reverse Total Shoulder Arthroplasty

Reverse total shoulder arthroplasty (RSA) is another treatment option for three and four-part proximal humerus fractures. RSA was initially developed to treat glenohumeral arthritis in the rotator cuff deficient shoulder. The implant design creates a more constrained joint that moves the center of rotation of the glenohumeral joint medial and distal to improve the mechanical advantage of the deltoid, thus providing function to rotator cuff deficient shoulders. Since the 1990's, RSA have become increasingly utilized for treatment of proximal humerus fractures. Advantages of RSA in the setting of proximal humerus fracture are that the outcome is less dependent on healing of the tuberosities (as is the case anatomic shoulder arthroplasty), or perfect reduction of the tuberosities. Furthermore, the biomechanical design of the RSA guards against underlying chronic or acute rotator cuff deficiency. Some studies have demonstrated better functional outcomes and pain relief with RSA when compared ORIF and hemiarthroplasty [47][48].

In patients with three- and four-part proximal humerus fractures, RSA is one of three main surgical options. Reverse total shoulder arthroplasty should be considered in elderly patients with un-reconstructable head-split fractures, irreducible cartilage defects, and patients at increased risk of failure of tuberosity healing [49][50]. Contraindications include deltoid insufficiency and permanent axillary nerve deficits, as well as acromial/scapular fractures that would de-tension the deltoid and glenoid fractures that preclude stable baseplate placement.

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