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REVIEW

Optimal Treatment of Proximal Humeral Fractures in the Elderly: Risks and Management Challenges

Hayden P Baker, Joseph Gutbrod, Michael Cahill, Lewis Shi

Department of Orthopaedic Surgery, the University of Chicago, Chicago, IL, USA

Correspondence: Hayden P Baker, Email hpbaker65@gmail.com

Abstract: Proximal humeral fractures (PHFs) are a common type of fracture, particularly in older adults, accounting for approximately 5–6% of all fractures. This article provides a comprehensive review of PHFs, focusing on epidemiology, injury mechanism, clinical and radiographic assessment, classification systems, and treatment options. The incidence of PHFs varies across regions, with rates ranging from 45.7 to 60.1 per 100,000 person-years. Females are more susceptible to PHFs than males, and the incidence is highest in women over the age of 85. The injury mechanism of PHFs is typically bimodal, with high-energy injuries predominant in younger individuals and low-energy injuries in the elderly. Clinical assessment of PHFs involves obtaining a thorough history, physical examination, and evaluation of associated injuries, particularly neurovascular injuries. Radiographic imaging helps assess fracture displacement and plan for treatment. The Neer classification system is the most commonly used classification for PHFs, although other systems, such as AO/OTA, Codman-Hertel, and Resch classifications, also exist. The choice of treatment depends on factors such as patient age, activity level, fracture pattern, and surgeon expertise. Nonoperative management is typically preferred for elderly patients with minimal displacement, while operative fixation is considered for more complex fractures. Nonoperative treatment involves sling immobilization followed by physiotherapy, with good outcomes reported for certain fracture patterns. Operative management options include closed reduction and percutaneous pinning (CRPP), open reduction and internal fixation (ORIF), or arthroplasty. CRPP is suitable for specific fracture patterns, but the quality of reduction is crucial for favorable outcomes. ORIF is used when CRPP is not feasible, and various surgical approaches are available, each with its advantages and potential complications. PHFs are a significant clinical challenge due to their prevalence and complexity. Treatment decisions should be patient centered based on patient factors and fracture severity.

Keywords: proximal humerus, fracture, elderly, management, shoulder arthroplasty

Epidemiology and Injury Mechanism

Proximal humerus fractures (PHFs) make up about 5–6% of all fractures and are the third most common fracture in older adults.[1–4] The incidence of PHFs varies depending on the region. In a study conducted in Southern Europe from 2016 to 2018, the incidence rate of PHFs was 60.1 per 100,000 person-years.[5] Meanwhile, in Australia, the incidence rate was found to be 45.7 per 100,000 person-years in 2017.[6]

Females are more prone to sustain PHFs than males;[3] the incidence rate of PHFs among females in Southern Europe was 89.3 per 100,000 person-years, compared to 28.2 in men.[5] In Australia, women over the age of 85 had the highest incidence rate of PHFs at 711.8 per 100,000 person-years in 2017.[6] The injury mechanism of PHFs varies by age and is typically bimodal, with high-energy injuries occurring largely in younger individuals and low-energy injuries in elderly individuals.[3,5]

Incidence rates of PHFs have increased over the past three decades. For example, in Australia, the yearly incidence of PHFs increased from 28.5 per 100,000 in 2008 to 45.7 per 100,000 in 2017.[6] Similarly, in New York City, the incidence rate of PHFs increased from 15.35 per 100,000 in 1990 to 19.4 per 100,000 in 2010.[7]

Clinical and Radiographic Assessment

When evaluating patients with a PHF, it is important for surgeons to obtain a thorough history and physical examination, paying close attention to the patient's overall functional status, such as their activity level, handedness, and living

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situation. Prior shoulder trauma or rotator cuff dysfunction should also be assessed to determine available treatment options. Additionally, associated injuries, such as head trauma or concomitant extremity fractures, should be evaluated, especially in elderly or comorbid patients.

Surgeons must also be mindful of potential neurovascular injuries during the clinical evaluation of PHFs. Treating surgeons should assess for brachial plexus or axillary nerve injury, with special attention to active firing of the deltoid. Neurologic injury is a significant consideration during the clinical assessment of patients with PHFs.[8–10] Visser et al reported that two-thirds of PHFs had an associated neurologic injury, with the axillary, suprascapular, and radial nerves being the most commonly injured.[11] Distal pulses should be palpated in every case, and Doppler ultrasound can be used to assess for vascular injury in cases where there is clinical concern.[11]

Radiographic imaging, including anteroposterior, true anteroposterior, scapular Y, and axillary views, provides helpful information for typical displacement associated with PHFs. If traditional axillary radiographs cannot be obtained due to patient tolerance, "trauma axillary" or Velpeau views may be alternatives.

CT imaging is indicated when fracture lines are not clearly delineated in complex fracture patterns and it can be a useful tool to assist with pre-operative planning.[9,10] Magnetic resonance imaging plays a limited role with acute PHFs, and it is occasionally used to evaluate injury to the rotator cuff or diagnose non-displaced greater tuberosity fractures.[8,12]

In elderly individuals, PHFs are often considered fragility fractures. Thus, treating surgeons should consider referring patients with acute PHFs to endocrinology or a bone health provider and prescribe vitamin D and calcium supplementation.

Classification

Ernest Codman first established an early classification system for PHFs in 1934.[13] He based his classification on the involvement of four anatomic parts, including the articular surface, humeral shaft, lesser tuberosity, and greater tuberosity. However, his classification did not take into account fracture displacement or differentiate between surgical and anatomic neck fractures.[14]

PHFs are most frequently classified using the Neer classification system.[15] Neer expanded on Codman's four anatomic segments by quantifying and qualifying fracture displacement. He defined fracture fragments as an individual part if there is greater than 1 cm of displacement or angulation greater than 45 degrees. Thus, fractures are defined by the number of parts involved (one-part through four-part). Neer used this approach to further classify displaced fractures into six sub-groups, including minimal displacement, displaced surgical neck fracture, displaced anatomic neck fracture, displaced lesser tuberosity fracture, displaced greater tuberosity fracture, and fracture-dislocation. Despite the wide adoption of the Neer classification system, its overall intra- and inter-observer reliability remains fair to moderate.[16]

Other less commonly used classification systems are the AO/OTA, Codman-Hertel, and Resch classifications. The AO/OTA classification was developed in the 1980s and classifies PHFs on dislocation, anatomic location, and articular surface involvement.[17] It divides PHFs into three main fracture types (unifocal extra-articular, bifocal extra-articular, and articular) which are then categorized into 27 subgroups based on impaction, degree of displacement, and dislocation of the fracture fragments. Importantly, valgus impacted PHFs are classified by the AO/OTA classification system, which previous classification systems did not include.

Hertel et al developed the Codman-Hertel classification system in 2004 to quantify predictors of fracture-induced avascular necrosis of the humeral head.[18] Hertel's group was first to describe proximal humeral fracture morphology as a significant predictor of fracture-induced humeral head ischemia. Fracture morphology is observed to be important predictors of fracture-induced humeral head ischemia, including fractures extending into the medial calcar (<8mm), disruption of the medial hinge, head splitting fractures, and fracture dislocations.[18] The Resch system focuses on varus and valgus impacted fractures.[19,20] Majed et al investigated the inter-rater reliability of PHF classification systems and found that Codman-Hertel had the highest and AO/OTA the lowest inter-rater reliability.[21]

Treatment Overview

The preferred treatment for PHFs has been the subject of much debate among medical professionals.[8–10,22,23] According to a Cochrane review that examined 23 randomized trials involving 1238 patients, there is currently insufficient evidence available to guide the treatment of PHFs.[24] Factors such as the patient's age, medical history, and the fracture classification/morphology all contribute to the surgeon's decision-making process.[8] Therefore, it is essential that surgeons engage in informed and personalized conversations with patients regarding the full range of treatment options that are available to them, taking into account the specifics of their injury and circumstances, as well as their own technical expertise.

Non-Operative Management

Nonoperative treatment is the mainstay of treatment for most PHFs in the elderly. Around 65 to 85% of PHFs are typically managed without surgery, especially in patients with minimal fracture displacement or patients that have contraindications to surgery.[2,6,25] Nonoperative treatment is recommended if the following five criteria are met:[26,27] 1) there is impaction between the shaft and head, 2) humeral head is located, 3) minimal coronal plane angulation (head shaft angle 100–160), 4) minimal tuberosity displacement, and 5) minimal involvement of the articular surface. Certain fracture patterns, such as one-part lesser or greater tuberosity fractures,[28] impacted two-part surgical neck fractured[3]c, and one-part humeral neck fractures are good candidates for nonoperative management.[26,29,30]

The non-operative approach typically involves sling immobilization followed by physiotherapy.[8,10,31] Options for immobilization include cuff and collar, standard sling, hanging arm cast, shoulder spica cast, and airplane splint; however, hanging arm and shoulder spica casts are largely historical and not utilized clinically anymore.[8] Functional bracing is not effective for PHFs, unlike humeral shaft fractures, as the rotator cuff pull on the fracture fragments causing a deforming force that cannot be neutralized externally.[25] Earlier initiation of physiotherapy, within 14 days from injury, has been shown to be correlated with better functional outcomes for the patient.[31]

The literature suggests that there may not be a significant difference in functional outcome among PHFs treated operatively and nonoperatively, particularly for more displaced fractures in elderly individuals. In a study of 125 patients treated non-operatively for valgus impacted PHFs, 80.6% achieved good or excellent outcomes.[32] In contrast, several studies have reported poor functional outcomes for non-operative treatment of PHFs, as well as inferior functional outcomes to those from surgical management.[33–35] A randomized trial performed by Handoll et al showed similar 2-year patient-reported outcomes between operative and non-operative management of displaced PHFs.[36]

Complications of non-operative management of PHFs include avascular necrosis, malunion, and nonunion (especially regarding the tuberosities).[8,18,35] Other complications include injury to the rotator cuff and shoulder stiffness.[8,18,35] It has been estimated that 7% of non-operatively treated PHFs will show delayed union or nonunion.[35] The PROFHER trial, the single largest randomized controlled trial investigating PHFs, found no significant difference in complication rates between surgical and nonsurgical treatment.[36] The effectiveness of nonoperative versus operative treatment methods for PHFs remains a topic of debate, with differences in outcomes reported between studies and fracture types.

Operative Management

For patients presenting with PHFs several factors must be considered including patient's functional status, fracture severity, and the surgeon's experience and skill. Operative fixation can be considered in patients with displaced two-, three-, and four-part proximal humeral fractures.[26,27,37,38]

Closed Reduction and Percutaneous Pinning

The fixation of PHFs via open reduction and internal fixation may lead to an acceptable reduction and stable fixation; however, it often requires significant exposure. In contrast, minimally invasive techniques, such as closed reduction and percutaneous pinning (CRPP), may offer benefits such as less soft tissue stripping, lower rates of avascular necrosis, higher union rates, reduced scarring, and improved cosmetic outcomes.[39] Nonetheless, percutaneous techniques have fallen out of favor with most upper extremity, sports medicine, and trauma surgeons preferring to open reduce fractures in young patients where surgery is recommended.[40]

Fracture patterns that are suitable for CRPP include two-part fractures involving the lesser tuberosity, greater tuberosity, or surgical neck; three-part surgical neck fractures involving either the lesser or greater tuberosity; and valgus-impacted four-part fractures. However, head-split and anatomic neck fractures are not recommended for CRPP.

CRPP is a technically difficult procedure that can be successful if the bone quality is good, there is minimal comminution with a stable closed reduction, the medial calcar is intact, and the patient is cooperative. If closed reduction does not allow for acceptable length alignment and rotation, then open reduction and internal fixation should be used. This decision can be made intraoperatively if closed reduction is not successful.

Clinical outcome has been shown to be directly correlated with quality of reduction for PHFs fixed percutaneously.[41] Therefore, there is minimal benefit to limited exposure if the fracture cannot be reduced acceptably. Before draping the patient, the surgeon can attempt closed reduction under fluoroscopy and determine the likelihood of obtaining an appropriate reduction. The decision regarding final fixation construct should be made by the surgeon intra-operatively. The surgeon should have the appropriate instruments available should they need to bail out to open reduction and internal fixation or arthroplasty. Fracture comminution and poor bone quality are relative contraindications against CRPP. Multiple studies have attributed pin loosening and poor bone quality to loss of reduction.[39,41]

Closed reduction techniques are described based on the fracture pattern and deforming forces. Techniques of closed reduction are performed by counteracting the direction of deforming forces. Fixation is typically performed with precise placement of percutaneous Schantz pins under fluoroscopy. Meanwhile, tuberosity fixation is often accomplished with cannulated screws.[42] The most common complication of CRPP is pin migration,[43] which can result in loss of fixation and damage to nearby neurovascular structures. Therefore, pins should be monitored closely and removed if signs of loosening. Other complications include infection, pin protrusion, avascular necrosis (AVN), loss of reduction or varus malunion. In several studies, CRPP has demonstrated favorable results.[44–46]

Open Reduction and Internal Fixation

Patients who do not meet criteria for CRPP may benefit from open reduction and internal fixation (ORIF). Primary arthroplasty may be beneficial for elderly patients who have head splitting fractures that cannot be reconstructed, severe valgus impacted fractures that have disrupted the medial periosteal hinge, fractures without any soft tissue attachments, and displaced multi-part fractures with delayed presentation.[38,47]

The deltopectoral approach has traditionally been the most common approach used for fixing PHFs. However, the deltoid-split approach offers an alternative option that provides better access to the greater tuberosity and articular surface. Although the deltoid-split approach provides better access to the greater tuberosity and humeral shaft for plating, it does carry an increased risk of axillary nerve injury,[37,38,48–50] and late deltoid insertion pull off when compared with the deltopectoral approach.[51] Reducing a displaced greater tuberosity fragment can be difficult through a deltopectoral approach; however, the surgeon can improve visualization of the retracted fragment by passing suture through the insertion of the rotator cuff at the greater tuberosity and drawing the fragment anteriorly. Both approaches have advantages and disadvantages and the decision on what approach to utilize should be influenced by the fracture pattern and surgeon experience.

Restoring length, alignment, rotation and anatomic reduction of the joint surface is the goal of operative fixation of PHF. After accessing the glenohumeral joint, the surgeon typically first dis-impacts the humeral head, reduces, and preliminarily fixes it with pins into the articular surface. The next step is either reduction of the tuberosities to the humeral head or reduction of the head to the proximal shaft. Kirschner wires and/or unicortical plates are often utilized to help the surgeon achieve and preliminarily fix an anatomical reduction.

Post reduction, displaced PHFs frequently show a degree of instability. Thus, adjuvant techniques are used for stabilization and avoiding early displacement. Morselized autograft or allograft is used to fill cancellous metaphyseal bone defects.[26,52,53] A locking plate can be used in the posteromedial calcar to provide a more stable buttress. Meanwhile, a fibular strut graft can also be used to help restore stability.[26,50,54] Severe comminution in an elderly patient may require impaction of the shaft within the humeral head to restore stability.[26]

With the fracture reduced, the plate must be placed posterior to the bicipital groove on the lateral aspect of the proximal humerus 10–15 mm distal to the greater tuberosity.[55] When feasible, it is advisable for the surgeon to try to insert screws in the calcar and lower region of the humeral head since the bone in the anterosuperior quadrant is the weakest.[51,56,57] The screws in the medial calcar hold the most significance in the overall structure and should determine the cranial/caudal placement of the plate. To prevent the screws from penetrating the joint, they should be positioned 5 to 10 mm away from the articular surface.[26] The screws situated in the superior region pose the highest risk of joint penetration.

Open Reduction Internal Fixation with an Intramedullary Nail

In certain cases, intramedullary nails (IMN) are preferred to proximal locking humerus plates for fixation of PHFs.[58] Several techniques are described for intramedullary nailing of PHFs. In a preferred technique, the surgeon first makes an incision that is lined up with the acromion's anterior border and extends distally, using blunt dissection to access the subdeltoid space. After gaining access to the supraspinatus muscle, a longitudinal incision is made to expose the articular margin of the humeral head where a straight humeral IMN is inserted. If using a curved IMN, its entry point should be placed more lateral through the rotator cuff insertion. Reduction is usually obtained percutaneously.

With reduction confirmed, the surgeon uses a guide wire (along with an awl and reamer) to form an entry site for the IMN proximally. Using fluoroscopy, the IMN is inserted such that its proximal end is no less than 5mm below the cortex of the head to prevent penetration. Correct trajectory is confirmed with rotation of the arm anteriorly to match the retroverted axis. The next step is placement of locking screws, which includes placing unicortical screws proximally and bicortical screws distally to lock the IMN into its correct orientation. C-arm fluoroscopy is used to verify that the glenohumeral joint has not been penetrated. Supraspinatus muscle fibers and injury to the rotator cuff, if present, are then addressed.

Complications following ORIF include infection, nonunion, malunion, AVN, early fixation failure, and arthrofibrosis. Depending on their clinical presentations, patients experiencing complications from open reduction and internal fixation may be recommended for conversion to arthroplasty.

Several studies have compared open reduction and internal fixation to arthroplasty, but conclusions were limited.[59] Other studies have demonstrated a significant decrease in loss of reduction and screw cut out among the intramedullary nail group compared to the locking plate group.[60] Furthermore, straight IMNs demonstrated decreased rates of loose screws and rotator cuff injury when compared to curved IMNs.[61]

Reverse Total Shoulder Arthroplasty

Reverse total shoulder arthroplasty (RSA) is popular approach for three- and four-part PHFs. RSA has several advantages, including that the outcome is less reliant on flawless tuberosity reduction and healing. Moreover, this surgical approach aims to prevent deficiency of the rotator cuff. Indications for RSA include elderly patients with irreparable cartilage damage, an articular head split, or an injury that will likely interfere with healing of the tuberosities.

RSA commonly employs the deltopectoral approach. With the approach complete, the biceps is tenodesed at the level of the pectoralis major tendon. If tuberosities are fractured, then they should be tagged with high strength sutures. Otherwise, the tuberosities are osteotomized. Then, the humeral head is removed and bone is harvested for grafting. The next step is exposure of the glenoid, which is a significant aspect of the overall operation. Once adequate visualization is achieved, preparation of the glenoid follows. The surgeon then places a large glenosphere and the humerus is reamed. While press-fit fixation of the humeral stem is preferred, cement fixation is frequently required. Pilot holes are created in the humeral shaft and are used for fixation and reduction of the tuberosities.

According to several meta-analyses, RSA shows superior functional outcome scores and improved reduction in pain than hemiarthroplasty and ORIF.[62–65] RSA was also found to have favorable complication rates and lower rates of revision procedures.[66] However, some of the literature shows that RSA has higher complication rates when compared to hemiarthroplasty, while maintaining lower revision rates.[63] Long-term data on outcomes following RSA are limited. The maximum accepted age for RSA is still unclear, even though RSA shows superior outcomes to hemiarthroplasty and ORIF in individuals older than 70.[67,68]

Hemiarthroplasty

Hemiarthroplasty was historically a major surgical approach for complex PHFs.[8] Yet, other surgical methods including reverse total shoulder arthroplasty have become more widely utilized, limiting the use of HA. These limited indications for HA include four-part fracture dislocations and three- or four-part head-splitting fractures.[8] Moreover, with RSA being preferred in the elderly, HA has been limited to middle-aged patients.[8]

The deltopectoral approach is recommended for hemiarthroplasty.[8,69–71] The surgeon must carefully choose the correct prosthetic head size and height. Importantly, secure tuberosity fixation plays a significant role in the overall result of the procedure.

Complications for shoulder hemiarthroplasty most commonly involve improper tuberosity healing and rotator cuff dysfunction. In a cohort of 66 patients treated with HA, Boileau et al found that 50% of the cases resulted in tuberosity malposition.[72]

Regarding outcomes, Neer et al 1970 analysis showed satisfactory outcomes for HA in four-part fractures as compared to both closed and open approaches.[14] Since then, studies have shown varied outcomes of HA relative to other treatment methods.[73–76] Generally, recent literature suggests that HA is effective at pain reduction yet has not shown to consistently improve range of motion.[77–79]

Conclusion

In conclusion, PHFs are a common type of fracture, especially among older adults, comprising approximately 5–6% of all fractures.[1–4] The incidence rates of PHFs vary by region and gender, with higher rates observed in females and increasing over the past three decades.[5,6] When evaluating patients with PHFs, thorough clinical and radiographic assessments are crucial to assess associated injuries. Several classification systems exist to categorize PHFs based on fracture patterns, with the Neer classification being the most widely used. Treatment approaches for PHFs include both non-operative and operative management, with the choice depending on various factors such as fracture severity, patient activity level, and surgeon expertise.[80] Non-operative treatment is the mainstay for elderly patients with minimal displacement, while operative fixation may be considered for more complex fractures. Closed reduction and percutaneous pinning, open reduction and internal fixation, reverse total shoulder arthroplasty, and hemiarthroplasty are the most common surgical techniques employed. Both approaches have their advantages and potential complications. Ultimately, the choice of treatment should be tailored to each patient's specific circumstances and needs. Further research is needed to clarify the optimal management strategies for PHFs and improve patient outcomes.[24]

Disclosure

The authors report no conflicts of interest in this work.

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