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TRAUMA (MJ GARDNER, SECTION EDITOR)

Proximal humerus fractures

Mark J. Jo · Michael J. Gardner

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Abstract Proximal humeral fractures are extremely common injuries, and are one of the true osteoporotic fractures. Most fractures can be effectively treated nonoperatively, as the rich vascularity and broad cancellous surfaces impart a high propensity for healing. Additionally, many fracture patterns result in adequate bone contact and minimal displacement with acceptable alignment. Open reduction and internal fixation of displaced fractures can improve outcomes, depending on the pre-injury functional status of the patient. If operative treatment is selected, unique treatment challenges must be overcome, including obtaining and maintaining reduction of small bone fragments with strong muscle forces, often in osteoporotic bone. Many options are feasible, including plates, nails, sutures, and other novel devices. Locking plates are the most common device used, but technical detail is critical to minimize the risk of implant failure, loss of reduction, and reoperation.

Keywords Proximal humerus fracture · Locked plating · Complications

Introduction

Proximal humerus fractures are seen most commonly in the elderly population, following a low energy fall [1, 2]. For the most part, proximal humerus fractures can be treated conservatively with the anticipation that the fracture will heal and the patient will regain function in that shoulder. Most proximal humerus fractures are minimally displaced, low energy osteoporotic fractures and are effectively treated with conservative treatment. But for those that have moderate to severe displacement, the optimal treatment for the patient has not been fully elucidated. The treatment algorithm has continued to evolve. There have been improvements to the design, technology, and techniques for operative fixation and arthroplasty. Also, patients are now living longer and leading more active lifestyles. Their expectations for outcome have changed, and using chronologic age to categorize these fractures is becoming less relevant. The goals of treatment should be to maximize the function of the shoulder and to minimize the chance of treatment failure, all while working within the expectations of the patient.

Clinical evaluation

The initial evaluation of a patient suspected of having sustained a proximal humerus fracture should begin with a proper history and physical examination. Proximal humerus fractures are usually seen in association with falls in the elderly, and evaluation of these patients carries with it age-specific issues. Determining the reason that the patient fell may uncover more serious cardiac or neurological conditions. Abuse is often overlooked in this patient population and if suspected, should be properly reported. Elderly patients may be on an anticoagulation regimen due to cardiac arrhythmias or venous thrombosis history, and a supratherapeutic anticoagulation level may have led to the fall or have serious life threatening consequences after the injury. Obtaining a medical history with special attention to nutritional

M. J. Jo (✉) · M. J. Gardner
Department of Orthopaedic Surgery,
Washington University School of Medicine,
St. Louis, MO 63110, USA
e-mail: jom@wudosis.wustl.edu

M. J. Gardner
e-mail: gardnerm@wudosis.wustl.edu

status, osteoporosis, and diabetes may help with treatment planning, as well as long-term follow-up care. Patients should also be evaluated for their physiological age rather than their chronological age. An understanding of a patient's pre-injury activity level and their expectations following treatment can help guide the clinician. The patient's handedness, current occupation status, hobbies, and daily activities can all be important for decision-making. Also, whether the patient is a caregiver to a spouse or relative, or if the patient has a caregiver, is very important information that can help determine the functional needs of the patient. Finally, an assessment of the patient's ability to abide by range of motion restrictions and actively participate in physical therapy can help determine the best treatment plan.

A thorough physical examination is the next step in evaluation. Due to the poor skin quality in the elderly, signs of an open fracture, skin tenting, or impending necrosis should be quickly identified. Extensive bruising can be normal or be an indication of anti-coagulation therapy. Special attention should be placed on examination for potential concomitant injuries to the elbow, forearm, and wrist. Gross deformity of the shoulder or a pronounced subacromial sulcus may suggest an associated dislocation of the humeral head. A complete neurological evaluation of the affected extremity should be conducted, and particular attention should be paid to the axillary nerve. It is not necessary to test to motor function of the axillary nerve in the acute setting, as it can be very uncomfortable for the patient, but the sensory distribution of the axillary nerve should be evaluated. Injuries to the brachial plexus and vascular injuries are rare but should be ruled out.

Imaging

After a complete history and physical examination, a standard shoulder radiograph series of the affected shoulder, as well as any other suspected injuries, should be obtained. This consists of a true anterior-posterior (AP) view of the glenohumeral joint, a scapular-Y, and an axillary view. It is important that a complete series of adequate quality be obtained in order to accurately diagnosis the injury. The patient's discomfort may impede obtaining a complete series. The axillary view can be especially difficult, but is necessary to rule out a dislocation of the humeral head, as well as evaluate the tuberosities. Having an assistant hold the extremity or having the patient hold an IV pole can help with positioning. With modern digital films, the film can be removed from the cassette and either placed into the patients' axilla or folded against the patient's neck and shoulder to help obtain the proper view [3]. Another option is the Velpeau view, which allows the radiology technician to obtain an axillary view with the patient in a sling [4].

When evaluating the fracture for displacement and angulation, one must take into consideration the position of the patient at the time of the imaging. Many times, the initial shoulder series is taken with the patient in the supine position. This allows the arm to extend relative to the humeral head and may accentuate the deformity on the axillary view. Therefore, the axillary view should mainly be used to assess for dislocation of the humeral head and the displacement of any humeral head fragments or tuberosities, not for alignment with the shaft. Images taken with the patient in an upright position may change the position of the fracture and give a more accurate picture of the true displacement and alignment of the fracture. Therefore, radiographs should be taken upright when possible.

The indications for a computed tomography (CT) scan are not completely clear. It is up to the judgment of the clinician to determine the need and utility of obtaining a scan. In cases when an adequate shoulder series cannot be obtained or there is a suspicion of a coronal plane fracture of the humeral head, a CT scan may be helpful. A CT scan may also better define fractures of the tuberosities and their displacement, which are difficult to see on plain radiographs.

Magnetic resonance imaging MRI has not been widely used in the setting of a proximal humerus fracture. But recently, the importance of soft tissue injuries and the relation to the outcome following a proximal injury has come to light [5–7]. Although many patients in this age group have pre-existing rotator cuff pathology, there is some evidence that patients may develop an acute tear at the time of injury or during the recovery period. This is especially true in patients that sustain a fracture dislocation.

Treatment decision making

The indications to treat a proximal humerus fracture nonoperatively, with surgical fixation, or with arthroplasty, are still evolving. In the past, much of the treatment algorithm was based on radiographs and fracture classification systems. But due to the poor intra-observer reliability of classification systems, as well as the poor correlation with outcome, there has been less emphasis placed upon them [8–11].

Some indications for surgery are more straightforward. Patients who have sustained an open fracture, vascular injuries, or those that have repairable neurologic injuries, are usually indicated for acute operative intervention [12]. Operative fixation can provide stability if there is a need for any vascular or nerve repair procedures. Patients who have pre-existing neurologic impairment on the side of injury resulting from a stroke or a traumatic spine injury, or who lead very inactive lifestyles, may not benefit from any acute intervention and can be managed nonoperatively. Patients who are

medically unstable can be treated conservatively or treated in a delayed fashion once they are more physiologically stable.

For the most part, patients with a proximal humerus fracture can be treated successfully without operative intervention. Approximately 80 % of proximal humerus fractures are minimally displaced low energy injuries and are at low risk for future displacement, nonunion, or avascular necrosis, and have a high union rate with conservative management [13–15]. But for fractures with more severe displacement, the decision for the type of treatment becomes more difficult. Historically, indications for treatment have been heavily based on radiographs. Fractures with less than 30° of varus or valgus displacement of the humeral head and residual cortical contact are considered to be amenable to nonoperative management [8, 9]. Three-part and four-part fractures were historically considered poor candidates for either conservative management or operative fixation, and Neer's work originally recommended arthroplasty [16]. But with the development of locked plating, better results were reported with operative fixation for older patients [17], and there was an increase in fractures being treated with operative fixation [18]. A recent study has shown a 25 % increase in operative management of proximal humerus fractures in elderly patients, even though the incidence of proximal humerus fractures has not changed [18]. Conflicting reports have shown better functional outcome with operative fixation and others have shown equivocal results when comparing operative and conservative treatment [19••, 20].

The fracture pattern can also give clues to the risk of vascular injury to the humeral head and future risk of avascular necrosis. The longer the medial metaphyseal extension of the head, the more likely the vascularity to the humeral head is intact [21, 22]. Also, the severity of osteoporosis can affect the success of operative fixation. Measuring the cortical thickness of the diaphyseal bone can be a predictor of the bone mineral density, which can affect the success of operative fixation [23]. One should also evaluate the radiographs for osteoarthritis or signs of significant rotator cuff disease, as these can have an impact on outcome and treatment [24••].

Overall, the trend has been to move away from fracture classification schemes and to concentrate more on the patient's characteristics and expectations [19••, 25]. A patient's physiological age, lifestyle, and the expectations of the patient are vital to devise the best treatment plan for the patient. For a physiologically elderly patient, decreased range of motion may not substantially impact their lifestyle, but for a patient that leads a more active lifestyle, optimizing their outcome becomes more important [20]. It is important for the treating physician to discuss the options with the patient and weigh the options before formulating a plan.

Conservative management usually consists of a brief period of immobilization and early range of motion therapy. Closed reduction can be used to improve the alignment of the fracture. Conservative management of displaced fractures will almost certainly result in some degree of malunion and loss of range of motion, but this may be tolerated in some patients. Nonoperative management can avoid the complications associated with operative intervention, such as failure of fixation and the need for secondary procedures.

Options for operative management consist of closed reduction and percutaneous fixation; suture fixation; plates and screws or cables; or intramedullary fixation. Augmentation can include an intramedullary structural allograft, bone grafting, or the addition of osteobiologics. Operative intervention allows for improvement of the displacement and alignment, and provides stability to allow the fracture to heal in a more anatomical position. This can help to maximize the function of the shoulder. Operative intervention can also result in improved range of motion over conservative management [20].

Arthroplasty is best suited for patients that are at increased risk of osteonecrosis of the humeral head. Patients with a multifragmentary cleaved humeral head, an unreconstructable humeral head, or a humeral head devoid of any soft tissue attachments, may go on to osteonecrosis due to disruption of the vascular supply to the humeral head. Patients that have delayed presentation or patients with glenoid damage and wear may also be candidates for arthroplasty. Humeral head replacement can also be used as a salvage procedure following unsuccessful conservative or operative management.

Nonoperative treatment

Conservative management consists of a brief period of immobilization in either a sling or a Velpeau bandage, with early gentle range of motion exercises. The role of closed reduction for a proximal humerus has been discussed in the literature [19••]. Some fractures may reduce with gravity alone as the patient resumes ambulating, but for some fractures, closed reduction may improve the deformity and the amount of bony contact.

In the acute setting, pain control can be difficult for patients. Resting in a supine position allows the arm to extend at the fracture site, and leads to pain and discomfort. Placing the injured extremity in a sling and having the patient rest in an upright or semi-reclining position with some bolsters behind the arm can help to reduce the pain. Patients may also find it more comfortable to sleep sitting in a reclining position when they are at home. Patients and caregivers should be advised that prolonged immobilization can be detrimental to outcome. And that physiotherapy, which can be self-directed or in a formal setting, depending on the patient's wishes and abilities, should begin no later than two weeks after the injury [26, 27]. Initially, pendulum exercises will allow for range of motion without placing a weight-bearing stress on the fracture. After the patient is

more comfortable, finger crawl exercises along a vertical surface can help with overhead range of motion.

The major complications following conservative management are symptomatic nonunion, severe loss of motion, avascular necrosis, and posttraumatic arthritis.

Operative treatment

The goals of operative fixation are to restore the anatomy of the proximal humerus to allow for successful union and maximize function. The articular surface's relationship to the shaft must be restored to maximize range of motion as well as stability. The tuberosities must also be reduced to their anatomical position to maximize function of the arm by reestablishing the insertions of the rotator cuff. Operative management can consist of closed reduction and percutaneous fixation, suture fixation, operative fixation with plate and screw construct, or intramedullary fixation [12, 28]. Major complications following operative fixation are infection, nonunion, and failure of fixation. Failure of fixation of the head or tuberosities can be caused by poor bone quality or improper surgical techniques.

Closed reduction and percutaneous fixation

Percutaneous fixation minimizes the soft tissue disruption seen with other techniques of operative fixation. This can decrease the risk of avascular necrosis and nonunion of the humeral head. Minimal surgical dissection can also decrease the amount of scarring that occurs, and may allow for improved rehabilitation and range of motion [29]. The fracture is first reduced under fluoroscopic guidance and either Kirschner wires or screws are inserted percutaneously to stabilize the fracture [29–32]. Pins that originate in the shaft and are directed toward the humeral head should start at least 2 humeral head diameters distal from the superior-most aspect of the humerus, to avoid injury to the anterior branch of the axillary nerve. Proximal pins that secure the greater tuberosity should penetrate the medial calcar region at least 2 cm distal to the inferior margin of the humeral head. This can help to avoid injury to the axillary nerve and posterior circumflex artery. A thorough understanding of the anatomy is needed, as cadaveric studies have shown that the axillary nerve, cephalic vein, biceps tendon, and posterior humeral circumflex artery are all at risk with this technique [32, 33]. As this technique has a steep learning curve, a limited open technique to assist in reduction and wire placement may be warranted.

Suture fixation

This technique has been described as a method to treat proximal humerus fractures and avoid the complications associated with implant placement and arthroplasty [34, 35]. Using this method, nonabsorbable sutures are passed through the rotator cuff tissue and/or the bone fragments, in order to obtain and maintain the reduction. This technique avoids extensive soft tissue stripping and the risk of symptomatic implants. It also preserves the bone stock of the proximal humerus, which may allow for future procedures.

Plate fixation

Operative fixation of the proximal humerus has evolved over the years. Development of locking technology, as well as site-specific implant, has helped overcome some of the problems initially seen with operative fixation. Locking screws have improved the fixation of the head and soft metaphyseal, and often osteoporotic bone, frequently associated with these patients (Fig. 1). The number of proximal screw options and trajectories attempt to maximize the fixation in the head of the humerus. Conventional plating may still be used in the case of a young patient with good bone quality, or for the treatment of

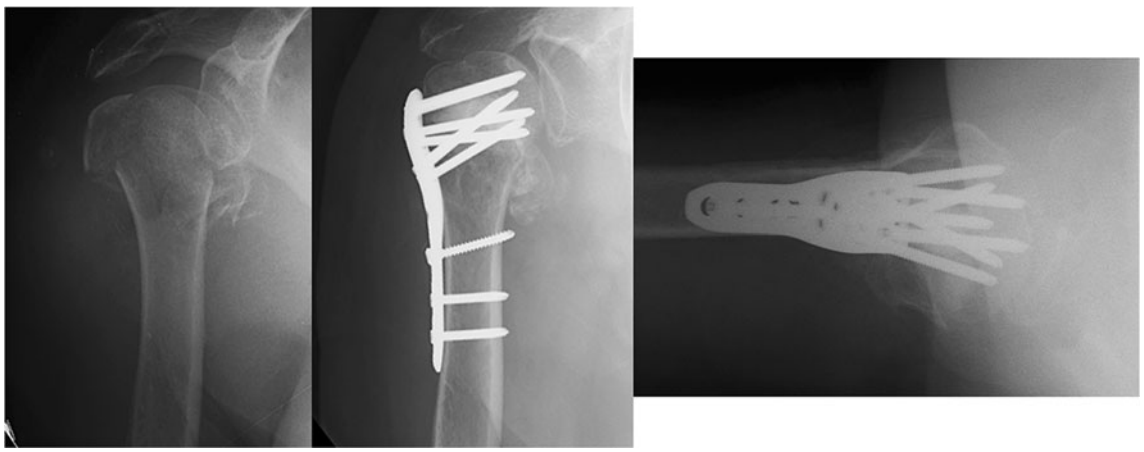

Fig. 1 A 60-year-old female fell from a standing height and sustained a displaced proximal humerus fracture with a head-splitting fragment. Accurate reduction of the articular surface, osteobiologic and suture augmentation, and locked plating led to an excellent clinical result

simple two-part greater tuberosity fractures. Successful treatment with either plating technique relies on bone quality, as well as the accuracy of reduction and humeral head viability [17, 19••, 20, 36]. The vascular and mechanical importance of the medial calcar region has been reported to contribute to the outcome following proximal humerus fractures, and should be restored whenever possible [21, 36]. Proper plate placement is important to avoid superior prominence, as this can lead to impingement when the arm is abducted. Accurate plate position also ensures the correct location and trajectory for the inferior humeral head screw, which may be critical to the stability of the construct [36]. The fixation of the tuberosities is also vital in regards to the outcome of the patient. Using a combination of the plate and screws, as well as osteosuture techniques of the fragments to one another and to the plate, can increase the strength of the fixation.

Intramedullary nail

The use of an intramedullary device has been advocated by some as an alternative to plate and screw fixation [37–43]. This technique is thought to be less invasive to the surrounding soft tissues. There has been concern regarding the disruption of the rotator cuff and injury to the footprint of the supraspinatus, but meticulous attention to dissection and repair of the supraspinatus tendon; establishing a starting point on the superior articular surface rather than the footprint of the tendon; and minimizing nail prominence, can decrease the chances of postoperative shoulder pain [44, 45]. Although the intramedullary nail fixation has been reported for two-part, three-part and fourpart proximal humerus fractures, currently the most appropriate patient is one that presents with a two-part surgical neck fracture [46, 47].

Surgical approaches

The deltopectoral approach to the proximal humerus has been the most widely used approach for operative fixation of proximal humerus fractures. Alternative approaches have been used to allow for improved access and ease of implant positioning [48–50]. Both the superior subacromial approach and the extended anterolateral acromial approach use a deltoid-splitting interval while protecting the axillary nerve to access the fracture site. These approaches decrease the amount of soft tissue dissection and retraction that often necessary with a standard deltopectoral approach and improve access to the lateral and posterior regions of the proximal humerus.

Augmentation

Structural and biologic augmentations have been used in the treatment of proximal humerus fractures to improve the rate of healing and decrease the chance of redisplacement. The use of autograft, allograft, cement, or bone substitutes can help to fill voids in the metaphyseal area as well as provide structure or biologic support to the fracture [51, 52••]. Endosteal fibular strut allografts have also been used to provide stability to the fracture especially in cases where there is loss of the posteriormedial calcar support and subsequent varus deformity [53].

Arthroplasty

The role of arthroplasty for the treatment of proximal humerus fractures has fluctuated over time. Neer initially recommended the use of humeral head replacement for complex three-part and four-part fractures [16]. Using conventional plating techniques, the incidence of nonunion and avascular necrosis of the humeral head was high for these types of injuries. But with the development of site-specific plates and locking plate technology, the fixation of proximal humerus fractures has improved and the role of arthroplasty for acute fractures has diminished. Humeral head replacement may still have a role in fractures that are associated with multifragmentary humeral head cleavage, unreconstructable humeral head, or humeral head devoid of any soft tissue rendering it avascular. Shoulder arthroplasty can also be used in the cases of delayed presentation or as a salvage procedure following failed operative fixation. The role for hemiarthroplasty in the elderly has also changed, as the functional results have been poorer than expected [54]. Also, the functional results have been shown to rely heavily on the successful healing of the tuberosities [55, 56]. With recent development and improvement in shoulder arthroplasty, the role of total shoulder replacement and reverse shoulder replacement has emerged. The need for an intact rotator cuff narrows the scope for a total shoulder replacement as preexisting, and acute rotator cuff pathology is frequent in this population [6, 7]. But in the cases where the humeral head is not salvageable, the rotator cuff is intact, and there is glenoid erosion or damage in a physiologically younger patient, total shoulder arthroplasty may be a viable option. Reverse shoulder arthroplasty does not require an intact rotator cuff, which is a benefit over hemiarthroplasty and total shoulder arthroplasty. This may be advantageous as both proximal humerus fractures and rotator cuff pathology are seen more frequently in the elderly population. Early results for the use of reverse shoulder arthroplasty have been encouraging, but further investigation is needed to fully elucidate their role [57].

Conclusion

Proximal humerus fractures are extremely common injuries, and with the increasing elderly population size of the elderly

population, the incidence of the osteoporotic proximal humerus is increasing. Treatment decisions depend largely on patient variables, specifically pre-injury function and activity expectations. Newer locking plates have expanded the role of open reduction of internal fixation, but these plates are not invariably associated with success, and fixation failure is common if applied to a malreduced fracture. In general, nonoperative treatment remains the mainstay for the majority of proximal humerus fractures.

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