Management Of Displaced Proximal Humeral Fractures

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Abstract

Treatment decision of displaced proximal humeral fractures is based on bone quality, fracture pattern, degree of displacement and patient profile. The AO/ASIF fracture classification helps in guiding treatment. Nonsurgical treatment consists of sling immobilisation. Surgical options include closed reduction and percutaneous pinning, open reduction and internal fixation with either conventional or locking plate and hemiarthroplasty. Planning should be done on an individual basis depending on patient and fracture characteristics.

Introduction

Proximal humeral fractures with a dual age distribution occurs either in young people following high energy trauma or in those older than 50 years with low velocity injuries like simple fall [1,2]. Three fourths of the fractures occur in older individuals with an occurrence three times more often in women than in men [1,3]. Most of the proximal humeral fractures are non displaced or minimally displaced and stable. These can be treated non operatively successfully with early rehabilitation. But severely displaced and comminuted fractures warrant surgical management for optimum shoulder function. Surgeons should be familiar with the different treatment options available. Treatment of this complicated fracture is guided by bone quality, fracture pattern, degree of comminution as well as patient factors such as age and activity level. Ultimate goal should be minimum shoulder pain and maximum range of motion. Surgical options include closed reduction and percutaneous pinning(CRPP), transosseous suture fixation(TOSF), open reduction and internal fixation with either conventional or locking plate and hemiarthroplasty. Fracture must be evaluated on individual basis and treatment tailored accordingly.

Anatomy

The dynamics of this highly mobile joint are the consequence of its particular bony anatomy and of its soft tissue envelope. The skeletal anatomy of the glenohumeral joint comprises two retroverted non-constrained articular surfaces. Mallon et al [4] have made measurements of the glenoid and found a mean transverse diameter of 24 ± 3.3 mm, a mean superoinferior diameter of 35 ± 4.1 mm, a mean posterior version of 2.0 ± 4.2° (-7 to -12) and a mean radius of curvature of 36.6 ± 7.4 mm (24 to 50). The proximal humerus has a cartilaginous surface which is tilted 45° upwards and about 20° posteriorly with reference to the distal intercondylar line [5]. Using radiological techniques, Cyprien et al [6] and Debevoise, Hyatt and Townsend [7] measured humeral retroversion. The former found a mean value of 26.9 ± 12.22° on the right and 21.2 ± 11.02° on the left. The latter group determined a mean value of 61.6° (47 to 65) on the right and 60.8° (47 to 85) on the left. The quasispherical surface of the humeral head occupies approximately one-third of a sphere with an angular value ranging between 120° and 150°. The radius of curvature in the axial plane is 22 ± 1.7 mm and the radius of curvature in the coronal plane is 24 ± 2.6 mm [8]. The vascular anatomy of the humeral head plays a major role in the outcome of trauma. A devascularised head will collapse and become incongruent, with the development of secondary arthritis. The arteria arcuata circulates within the humeral head and receives its blood supply from four major sources: the metaphyseal artery, the branch of the anterior circumflex artery in the bicipital groove, arteries from the rotator cuff and the medial branch of the posterior circumflex artery [9, 10, 11]. Because of this arterial pattern a fracture through the anatomical neck will lead to complete devascularisation of the fragment of the head which carries the articular surface. The power link between the scapula and the humerus is ensured by the glenohumeral muscle groups which directly cross the joint, namely the teres major, the deltoid with its three functionally independent anterior, middle and posterior segments, and the rotator cuff. The last consists of the musculo tendinous units of subscapularis, supraspinatus, infraspinatus, and teres minor [12]. The biceps and its tendinous long head may also be considered as part of the rotator cuff. The biceps tendon is a valuable surgical landmark separating the lesser from the greater tuberosity and therefore is of help in identifying the various fragments
with their attached cuff tendons when dealing with a displaced fracture of the proximal humerus. The structures medial to the biceps tendon are subscapularis and the lesser tuberosity while those lateral to it are part of the greater tuberosity and attached tendons of supraspinatus and infraspinatus [13]. The axillary nerve is at risk in these fractures [14]. It supplies the deltoid and teres minor muscles and should be tested for motor and sensory function on the lateral aspect of the shoulder before any attempt at manipulation for fracture of the humeral head. At operation it should be visualised or at least palpated, since it lies anterior to subscapularis before plunging beneath the tendon of subscapularis and the glenohumeral capsule into the quadrilateral space on its way to the deltoid and to teres minor. The integrity of the musculocutaneous nerve should also be checked clinically, including its motor innervation of biceps and the sensory supply to the medial forearm. It is usually not necessary to visualise the nerve at operation but it must be borne in mind that it enters the biceps approximately 5 to 8 cm below the tip of coracoid although this distance has been shown to be very variable [15]. Vascular lesions are infrequently associated with fractures of the proximal humerus [16]. In the presence of a fracture an enlarging ecchymosis or a painful tense haematoma should alert the surgeon to underlying haemorrhage which is either venous or, more rarely, arterial. Ideally, angiographic assessment should be considered. If this is not possible surgical exploration is mandatory.

Classification

The Neer classification [17] and the AO/ASIF classification [18] are the most widely used systems to evaluate and determine treatment of proximal humeral fractures. The Neer classification is based on the number of fracture parts (displacement >1 cm, angulation >45°), direction of dislocation, and involvement of the articular surface. The AO/ASIF classification system for proximal humerus fractures broadly groups fractures based on the degree of articular involvement and likelihood of vascular injury. Observer reliability and reproducibility for both the Neer and the AO/ASIF classification is fair to poor; it is unlikely that one orthopaedic surgeon will assign the same classification to a proximal humerus fracture at two separate times, just as it is unlikely that two orthopaedic surgeons will agree on a classification. Given these limitations, the AO/ASIF classification for the three basic types of humerus fracture is more user-friendly.

Pre operative assessment

For a successful diagnosis of a fracture of the proximal humerus it is imperative to have two views perpendicular to each other. The glenohumeral joint line should be completely open with no overlap of the head upon the glenoid. The most common standard projections are the true AP view of the glenohumeral joint perpendicular to the plane of the scapula and the axillary view parallel to this plane and perpendicular to the acromion. The axillary view necessitates only a few degrees of abduction or, if the arm is held in internal rotation by a bandage, a Velpeau view can be made in which the patient leans backwards with the x-ray beam directed superoinferiorly from the top of the shoulder on to a cassette located at the patient’s elbow. AP internal and external rotation views may be helpful but are difficult to obtain in cases of acute injury. Scapular Y views are sometimes of use but are notoriously difficult to interpret and, unless perfectly performed, should not be used to exclude, for example, posterior fracture-dislocations [13]. CT is a useful adjunct and three-dimensional reconstructions can show features not readily recognisable on plain films [19, 20, 21]. MRI may accurately delineate suspected soft tissue injury. In case of doubt angiography should be used to determine vascular integrity.

Management protocol:

Although the management of displaced proximal humerus fractures has evolved toward humeral head preservation, treatment should be guided by careful assessment of vascular status, bone quality, fracture pattern, and degree of comminution, as well as patient factors, such as age and activity level. Patients who are either medically unstable or inactive are poor candidates for surgery and instead may be treated with sling immobilization until the fracture heals. The ultimate goal is maximum shoulder function and minimal shoulder pain.

The likelihood of humeral head osteonecrosis is implicit in the AO/ASIF classification; thus, determining the AO/ASIF fracture type is the initial step in determining the probability of humeral head preservation. Type A is a unifocal, extra-articular fracture with an intact vascular supply. Type B is a bifocal, extra-articular fracture with possible injury to the vascular supply. Type C is an articular fracture involving the anatomic neck with a high likelihood of osteonecrosis. Cortical thickness of the humeral diaphysis is a more reliable and reproducible predictor
of both bone mineral density and the potential for success of internal fixation than is age [22]. After adjusting for magnification, medial and lateral cortical thickness is measured from the anteroposterior view of the proximal humerus [22]. The first level, the most proximal aspect of the humeral diaphysis, occurs at the level in which the endosteal borders of the medial and lateral cortices are parallel. The second level is 20 mm distal to the first level. The combined cortical thickness is the average of the medial and lateral cortical thickness at the two levels [22]. Nonsurgical treatment, suture fixation, and hemiarthroplasty may be the best options for the patient with combined cortical thickness.

Nonoperative treatment:

Nonsurgical management traditionally has been recommended for nondisplaced and minimally displaced proximal humerus fractures. Sling immobilization with or without closed reduction also has a role in the management of displaced proximal humerus fractures. Court- Brown and colleagues [23, 24] recommend 2 weeks of sling immobilization followed by physical therapy for patients with two-part surgical neck fractures [24] and valgus-impacted fractures [23]. Two-part proximal humerus fractures with >66% translation were treated with either a sling or with internal fixation with flexible intramedullary nailing and tensionband wires [23, 24]. No statistical difference was reported between the groups in terms of Neer score, [17, 25] return to activities of daily living, and fracture union [23, 24]. The data demonstrate that the raw Constant score deteriorates with advancing age and degree of displacement. However, when calculated based on age-adjusted Constant score, the older patients actually had better scores than did the younger patients [23, 24, 26, 27]. Therefore, sling immobilization is an appropriate treatment option for patients older than age 60 years with valgus-impacted, two-part surgical neck or two-part tuberosity fractures.

Surgical approaches:

Deltpectoral approach. In displaced fractures of the proximal humerus the most common surgical approach is the deltopectoral with the patient in the ‘beach-chair’ or semi-sitting position.3,4 General anaesthesia is used and sometimes a scalene block may be performed before intubation. This allows for lighter anaesthesia and the absence of pain on awakening will prevent uncontrolled movement by the patient and therefore protect the osteosynthesis. An oblique incision 15 cm long is made starting from below the clavicle and passing over the coracoid. After appropriate haemostasis of the subcutaneous tissue, the deltopectoral interval and the cephalic vein are identified. If there is difficulty in finding the interval because of swelling the search should be made more proximally near the clavicular insertion of the deltoide and pectoralis major muscles where, usually, the interval widens. The cephalic vein is left either with the deltoid muscle or with the pectoralis muscle. It may be ligated. The conjoined tendons are then retracted and a curved blunt retractor is placed under the deltoid muscle around the fragments of the humeral head in the subacromial space after blood clot and bursal tissue have been removed. The axillary nerve is identified and palpated by sliding the index finger under the conjoined tendons on to the anterior aspect of subscapularis. It is then important to locate the biceps tendon and to use it as a landmark to help to identify the fragments of the greater and lesser tuberosities with their attached tendons. With two-part fractures involving the surgical neck, the alignment of biceps may reflect the adequacy of the reduction. In a fracture in which the lesser tuberosity is not detached but where the surgeon wishes to inspect the articular surface, a small incision through the interval can be made and the articular surface observed. All the tendinous structures should then be identified with stay sutures. Reduction may be accomplished by various techniques from the use of plates and screws in particularly strong bone to obtain a ‘rigid’ fixation, to relying on osteosutures or wires to obtain a tension-band construct. This last technique may be particularly indicated in the presence of osteoporosis. A control radiograph should always be obtained before closure. In order to obtain a satisfactory view the x-ray tube should be placed on the contralateral side of the patient and the cassette applied to the body of the scapula. This will give a view perpendicular to the plane of the scapula allowing interpretation of the quality of the reduction and of the position of the tuberosities.

Transdeltoid split approach. In cases of isolated fractures of the tuberosity or if an intramedullary device is employed, it is sometimes sufficient to use a transdeltoid split approach. The patient is in a semi-sitting position and the skin incision may follow the direction of the muscle fibres along the upper deltoid at the junction of the anterior and middle thirds or as a vertical ‘sabre-cut’. The deltoid is split along its fibres no more than 5 cm from the acromion in order to avoid injury to the axillary nerve. The cuff is then identified and the haemorrhagic subacromial bursa partially removed. The fragments of the fracture are then identified and reduced. Fixation may be by means of isolated screws, wiring or heavy sutures. If proximal intramedullary nailing is chosen the same approach can be used. The tendon of supraspinatus is split to allow the introduction of the nail into the
tuberosity. The proximal part should be buried under the level of the articular cartilage. Imageintensifier control is essential to ensure a satisfactory outcome.

Operative treatment

Despite general agreement that displaced or more complex fractures should be treated operatively, there is no consensus on the type of surgical fixation that should be used. Various methods, such as closed reduction and percutaneous pinning (CRPP), tension band wiring, intramedullary nailing, plate fixation, and hemiarthroplasty have all demonstrated mixed results. Fracture pattern, fracture displacement, bone quality, preexisting rotator cuff disease or arthrosis, and patient function are important factors to consider in developing a treatment plan. The primary goal should be a construct sufficiently stable to begin early range of motion of the shoulder [28-34].

Displaced 2-part and some 3-part proximal humerus fractures may be managed with CRPP in selected cases. Alternatively, intramedullary nails (IM) designed specifically for proximal humerus fixation may be advantageous in some of these fractures. Open reduction and internal fixation (ORIF) has also been widely used in 2-part, 3-part, and 4-part fractures. Valgus-impacted 4-part fractures are less likely to have disruption to the humeral head blood supply and develop osteonecrosis; thus, ORIF is generally recommended for these injuries [35-39]. In contrast, displaced 3-part and 4-part fractures are associated with higher rates of osteonecrosis and other complications [25, 26, 35, 40-42]. Open reduction and internal fixation is advocated for patients who are young and active, but patients who are elderly may be better treated with hemiarthroplasty, depending on their bone quality and physiologic age [43-46]. Recent advances in internal fixation, with locked plate-screw constructs, have extended our ability to retain the humeral head in some of these patients [47]. The results and outcomes of internal fixation versus hemiarthroplasty in this group of patients have not been compared. The following discussion will review various surgical treatment options.

Percutaneous Pins

First described by Jaberg, this technique is demanding, but it can be very effective for unstable 2-part surgical neck fractures and even some 3-part or 4-part fractures in patients with good bone quality [48-50]. Closed reduction, with or without percutaneous assistance, is performed, and 2.5-mm terminally threaded Schanz pins are used to stabilize the fracture. Knowledge of the anatomy of the axillary and musculocutaneous nerves is essential in avoiding injury to these structures [42, 51, 52]. Pins should be placed in a divergent fashion to optimize stability. Three to 4 pins are directed proximally across the surgical neck fracture, and 1 or 2 pins are placed through the greater tuberosity into the medial cortex. These augment the fixation of the surgical neck fracture and will also stabilize a greater tuberosity fragment. Multiple, tangential fluoroscopic views should be obtained to avoid penetration of the articular cartilage. Passive range of motion is initiated postoperatively. Pins placed through the greater tuberosity will limit abduction until they are removed after 3–4 weeks. The other pins are removed after 6–8 weeks. Surgical trauma to the soft tissues and fracture fragments is minimized with percutaneous pinning. This results in less blood loss and scar tissue and better preservation of fracture biology compared with other techniques. One recent study reviewed 71 patients treated with percutaneous pinning, versus a cohort of patients matched for age and fracture pattern treated with ORIF. These authors noted that the incidence of osteonecrosis was higher after ORIF, potentially secondary to surgical trauma [50]. Percutaneous pinning is a viable option, particularly in young patients with suitable bone quality. It is speculated that earlier return of mobility and better final range of motion may also be possible with this method. However, complications include pin infections, loss of reduction, and pin migration. Careful patient selection will minimize these problems. This method is best suited to patients who have good bone quality and who can comply with postoperative activity instructions. It is not appropriate for anatomic neck fractures, fractures with humeral head comminution, or severely impacted fractures with valgus angulation. Rather, it works well for 2-part fractures and for 3-part fractures with minimal greater tuberosity displacement. Jaberg reported 95% fracture union after 6–8 weeks with CRPP but had 4 cases (7%) of pin tract infection [48]. Fenichel et al retrospectively reviewed 50 patients with unstable 2-part and 3-part proximal humerus fractures treated with this method [53]. They had no pin infections, osteonecrosis, or neurovascular problems. However, 7 patients experienced a loss of reduction, 3 of whom underwent revision fixation. They recommended careful patient selection and close follow-up in the first 4 weeks after surgery to minimize loss of reduction and fixation. Better functional outcomes were noted in patients who did not have an associated fracture of the greater tuberosity, which is consistent with the experience of other authors [42, 48, 49].

Intramedullary Nails

Intramedullary nails are effective in stabilizing some proximal humerus fractures [29, 54, 59]. Preservation
of blood supply through indirect reduction is an advantage of this technique. A greater propensity for maintenance of reduction is likely in 2-part surgical neck fractures as opposed to those with associated fractures of the tuberosities. Several manufacturers offer nails specifically designed for proximal humerus fractures, with multplanar locking, blade fixation for the proximal fragment, or both. These implants may be particularly useful for proximal humerus fractures in combination with humeral shaft injuries [54, 56]. Disadvantages include potential damage to the rotator cuff and chronic shoulder pain.

An anterior acromial approach is recommended for antegrade humeral nailing. This minimizes surgical trauma to the rotator cuff, versus a lateral acromial approach, which can injure the insertions of teres minor and infraspinatus muscles. Care should be taken to protect the axillary nerve. Blunt dissection and visualization to bone can protect the axillary nerve from damage when proximal interlocking bolts are directed from lateral to medial [60]. A lateral starting point or failure to achieve reduction of the proximal fragment will result in varus malalignment [56]. Meticulous technique and understanding of the associated anatomy and radiographic landmarks will prevent this problem. Displaced 2-part fractures are most amenable to nailing. If 3-part fractures are treated with this method, the greater tuberosity should be reduced and provisionally stabilized with Kirschner wires before the starting point for the nail is developed. Agel et al reported the results of 20 patients with proximal humerus fractures that were treated with a Polaris nail [55]. This implant has options for proximal interlocking in several directions. Although only 11 of 20 patients healed without any complications, this implant can be effective for certain fracture patterns. The authors cautioned against using a nail when the lateral metaphysis is comminuted or if the starting point extends into the greater tuberosity. In such cases fracture displacement, fixation failure, or both are more likely [55, 61]. Similarly, Rajasekhar et al also demonstrated success with this implant, in both young and elderly patients [57]. Their population of 30 patients included primarily 2-part fractures and had 80% satisfactory to excellent results. Other intramedullary implants more recently developed for use in proximal humerus fractures include proximal blade fixation or multplanar locking options, some with threaded screws to stabilize greater tuberosity and lesser tuberosity fragments [29, 56]. The early results of these implants appear promising, even in elderly patients [29].

Open Reduction and Internal Fixation:
Open reduction and internal fixation is an effective method of treatment for proximal humerus fractures. It is frequently used for displaced 3-part and 4-part fractures and valgus-impacted 4-part humerus fractures to promote early motion of the shoulder [35, 37, 38, 42, 62]. Multiple fixation options have been described, ranging from tension band fixation [25, 33, 63] to conventional large fragment and small fragment plates and screws [38, 46, 64-70] to new locked plate and screw constructs [47, 71-81]. No comparative clinical studies to date have been done to determine clear indications and limitations of these methods.

Conventional Plates:
A deltopectoral approach or deltoid-splitting approach may be performed, depending on the fracture pattern and surgeon experience [38, 39]. Care should be taken to preserve rotator cuff attachments and the humeral head blood supply in all cases [39, 46, 50, 67, 82-85]. Articular fractures should be anatomically reduced, and relationships of the tuberosities and their associated rotator cuff insertions should be restored. Shortening of the humerus, through impaction of a comminuted surgical neck fracture, may be desirable. This improves the stability of the construct by increasing the surface area of bony contact and providing an intact medial buttress [74]. Careful attention to safe implant placement is essential. Plates should not impinge on the acromion, the biceps tendon, or rotator cuff insertions. Screw trajectories should be strategic and divergent to optimize purchase in the humeral head. Central and inferior placement, with some screws in the medial cortex, may be beneficial [74, 86]. The fixation should ideally be rigid enough to promote early rehabilitation.

Initial reports of ORIF reviewed experiences with the AO large fragment T-plate [46, 66, 68, 87]. By Neer's criteria, Kristiansen et al reported only 45% satisfactory results for 3-part fractures [66]. Fixation failures and some of the poor results could be attributed to deficient bone quality in elderly patients. Placing the T-plate more inferiorly on the greater tuberosity avoids impingement on the acromion and increases the number of good results, particularly in 3-part fractures [48]. However, both of these early studies had high rates of intraarticular screw placement. Precise attention to surgical technique to ensure accuracy of screw placement will prevent this complication. In a group of younger patients (20–40 years old), 83% satisfactory results were obtained with careful placement of a T-plate or semitubular blade plate [87]. However, poor results were seen in patients with underlying rotator cuff damage. In an attempt to reduce complications associated with the use of the T-plate, Esser advocated a cloverleaf plate [64]. This is a small fragment implant with more options for
proximal fixation. It can be modified by removing the arm on the end of the plate to reduce the potential for prominence on the humeral head. In 26 patients with a mean age of 55 years who had 3-part and 4-part fractures, 92% good results were obtained with no nonunions and no osteonecrosis [64]. Other authors have reported success with this method [38, 42, 46, 62] and by applying principles of indirect reduction and fixation with meticulous attention to the surrounding soft tissues. Semitubular plates may be fashioned into a blade plate for displaced 2-part and 3-part fractures. This technique may provide improved fixation of the humeral head, depending on the length of the blade and the quality of the bone [88, 89]. Several reports have described good results with few hardware complications [69, 70, 87]. Similarly, 3.5- or 4.5-mm blade plates may be created by bending standard limited contact dynamic compression plates. These are useful for treating acute fractures or nonunions [90-92]. More recently, 3.5- and 4.5-mm blade plates have been developed by various manufacturers. Moderately good outcomes have been demonstrated, even in elderly patients [65, 93] as a result of more rigid fixation of the humeral head. This method is effective for displaced 2-part fractures and can be used in 3-part fractures after reduction and fixation of the greater tuberosity. Some prefabricated blade plates designed for the proximal humerus have a cannulated system to facilitate accurate blade placement. Meier et al reviewed 42 consecutive patients treated with a customized, cannulated, 110-degree blade plate [67]. They described indirect reduction of the humeral head fragment and restoration of the head neck angle, while minimizing implant prominence and proximity of the plate with respect to the acromion. This fixation was sufficiently stable to permit early rehabilitation. However, 8 patients in their series (19%) had perforations of the humeral head by the blade because the fractures collapsed during the healing process. The authors speculated that the valgus angle of their implant, versus 90-degree blade plates in other reports, permitted protrusion of the blade. To prevent this complication, 90-degree blade plates are recommended. Collectively, these reports suggest that open reduction to restore relationships of the shoulder joint, along with rigid internal fixation to initiate early range of motion, will optimize functionality [31, 62, 67]. It appears that alignment is less important than achieving a stable construct to permit early range of motion of the shoulder [28, 32-34, 94]. No conclusive information exists from randomized controlled trials comparing ORIF with nonoperative management [32, 33, 95, 96]. Furthermore, none of the clinical studies to date have compared different types of fixation; thus, large randomized trials are necessary to determine the optimal type of treatment for various proximal humerus fractures.

Locking Plates:
Several new locked plate-screw devices have been developed over the past few years. Research suggests plates with attached (locked) screws may provide improved fracture stability and healing. When a screw is locked to the plate, a fixed point of contact is created, which may be advantageous in the cancellous bone of the proximal humerus, especially in elderly patients with osteoporosis [97-100]. Locking plates specifically designed for the proximal humerus have favorable shapes and screw configurations, which may enhance maintenance of reduction and reduce hardware complications.

Biomechanical data suggest some advantages to locking plates [101, 102]. One early study of an experimental precursor to locking plates reported greater stiffness and increased energy to failure when compared with an AOT-plate [103]. In osteoporotic bone, torsional stiffness was improved when locking plates were compared with cannulated 90-degree blade plates in a cadaver surgical neck fracture model [100]. However, no difference was seen with bending loads in the same model. Conflicting information has been published regarding the performance of intramedullary nails in the proximal humerus compared with locking plates. In a surgical neck, gap osteotomy, cadaver model the nail has demonstrated superior stiffness with axial loading [104] as well as torsional and bending loads [104, 105]. However, Edwards et al found more stiffness in torsion and bending and less displacement of a locked proximal humerus plate compared with a nail in a similar model [106]. They concluded that locking plates may be particularly advantageous in osteoporotic bone. Some 3-part and 4-part fractures and head-split fractures are not amenable to nailing, so the clinical applicability of such biomechanical information is limited. Individualized decision making is essential when choosing among these implants in the clinical setting, with consideration to fracture pattern and underlying patient factors including bone quality, rotator cuff pathology, or associated injuries. Early clinical results of locking proximal humerus plates have been promising, although no comparisons with other techniques have been published [47, 71, 73, 75-80]. Despite the paucity of literature to date and increased implant costs, surgeons have begun to use locked plating for both simple and complex proximal
humerus fractures based on the theoretical benefit of improved fracture stability [75, 77]. As with other methods of ORIF, a deltopectoral or deltoid-splitting approach may be used, depending on the fracture pattern and surgeon experience [39, 107]. It is important to reduce the fracture fragments prior to locking screws to the plate. The plate may be used to aid the reduction. Nonlocked screws can compress the plate to the bone, and nonlocked screws may also be used to achieve interfragmentary compression. This should be done prior to placing locked screws. The locked screws will then serve to protect the reduction [102]. Care should be taken to maintain the appropriate angle when seating screws into the plate. This will prevent cross-threading and may minimize screw disengagement from the plate over time [72, 73, 76, 108]. The presence of medial column support will improve the stability of the construct and minimize early loss of reduction [74]. Gardner et al defined medial column support as an anatomic or slightly impacted reduction, along with a superior directed oblique locked screw in the inferomedial region of the proximal fragment [74].

The largest series of locked plating in the proximal humerus was recently reported by Kettler et al [76]. These authors reviewed 176 patients treated with the PHILOS plate. Technical errors included 11% with screw perforations into the glenohumeral joint. Another 11% had secondary displacement of the implant from the humeral head or shaft, and 14% had malunions [76]. Strict attention to fracture alignment and implant placement may prevent some of these complications. Bjorkenheim et al [71] described 72 patients with a mean age of 67 years with isolated proximal humerus fractures treated with the LCP proximal humerus plate. Half achieved a good or excellent constant score after 1 year follow-up. Elderly patients and those with C-type fractures (displaced articular and/or anatomic neck fractures) [108] had worse functional scores. Only 3 cases of osteonecrosis and 2 nonunions were identified, but 19 fractures (26%) settled into varus position. Initial varus malreduction has been noted to increase the risk of fracture fixation failure [71]. Fankhauser et al noted loss of proximal screw fixation and varus malalignment in 3 of their 29 patients treated with locked plating [73]. They recommended augmenting the proximal fixation with sutures placed through the rotator cuff and attached to the LCP plate. They also had 2 patients with osteonecrosis and 1 with plate failure. Constant scores averaged 75 for all patients, and worse scores noted were again associated with C-type fractures.

Other recent reports have focused on limiting surgical trauma while reducing and stabilizing the proximal humerus fracture with a locking plate. A minimally invasive deltoid splitting technique can be used without damage to the axillary nerve if screws are limited to superior and inferior holes [109]. Gallo et al advocate 2 incisions with a delto pectoral exposure for the shaft and head and a lateral approach to the greater tuberosity [107]. The plate can then be directed through the lateral wound and used to stabilize the fracture. Surgical trauma to the deltoid is minimized, and maintenance of the reduction and accurate implant placement may be facilitated with this method. It may be particularly effective in patients who are obese or those with large shoulder muscle mass. Irrespective of the type of plate used, meticulous surgical technique will maintain the biology around the fracture to promote healing and diminish the occurrence of osteonecrosis. This will also minimize scar tissue and soft-tissue damage, which can impair mobility and function.

Early rehabilitation and restoration of functional mobility of the shoulder is the key to success after nonoperative management of these injuries [28-33, 94]. Similarly, the success of surgical treatment depends on maintaining the reduction to promote early rehabilitation [31, 33, 110]. Perhaps the best indication for surgical treatment is to maintain an adequate, stable fracture reduction to initiate early range of motion. It is possible that locking plates used for unstable proximal humerus fractures permit more aggressive postoperative rehabilitation and thereby facilitate more rapid return to productive function. It appears that the benefit of locked plating is in those cases where adequate fixation via other methods is not possible. Locking technology is not necessary for many types of proximal humerus fractures, and its use generates substantial implant expense. The specific indications, limitations, and cost effectiveness of the locked plating in the proximal humerus warrant further study.

Hemiarthroplasty: Hemiarthroplasty remains a useful option for older patients with anatomic neck and head-split fractures [36, 44, 45, 110-117]. It is controversial whether to treat functional elderly patients with 3-part and 4-part fractures with hemiarthroplasty versus ORIF [47, 118]. Displaced 4-part fractures are associated with osteonecrosis in 21% to 75% of cases, compared to 8% to 26% of valgus-impacted 4-part fractures [40-42, 46, 102]. This has been 1 argument favoring hemiarthroplasty in elderly patients with displaced comminuted proximal humerus fractures. However, in some cases the presence of osteonecrosis may not be painful. It is interesting that osteonecrosis may be present in only a portion of the humeral head and may...
not result in collapse in all patients [46, 53, 67, 83, 85]. Thus, the age of the patient, the quality of the bone, the fracture pattern, and amount of comminution are all important considerations in developing a treatment plan. The advent of locking plates has improved our ability to stabilize some fractures and has likely reduced the frequency of hemiarthroplasty in the acute setting for proximal humerus fractures. In some cases it may be impossible to achieve adequate stability with a plate and screws, and a decision to perform hemiarthroplasty is made intraoperatively [46, 75]. It is prudent to prepare for this ahead of time and to discuss both options with patients. It is unknown whether patients function better over time after ORIF versus hemiarthroplasty. However, early treatment of displaced fractures, versus delayed hemiarthroplasty, results in fewer complications and better functional results [45, 119-121]. This is likely the result of extensive scar tissue, distortion of the anatomy, and chronic disuse of the shoulder when these fractures are treated with late arthroplasty.

A recent analysis of literature to date on 4-part proximal humerus fractures concluded that insufficient evidence exists to define the optimal treatment for these injuries [95]. Little comparative information also exists when determining the outcomes of ORIF versus hemiarthroplasty. Only 1 randomized controlled trial has been undertaken to date. Tension band wiring was compared to hemiarthroplasty in a total of 30 elderly patients [122]. A potential 91% reduction in risk of reoperation was seen with hemiarthroplasty. Extrapolation of these findings to a younger population cannot be done. Furthermore, no comparative information exists regarding the complications and functionality of hemiarthroplasty compared with more modern methods of internal fixation, including standard plates and screws or locking plates. Because current literature is insufficient to promote clinical decision-making, larger trials and randomized studies are needed [95, 96].

Patients who undergo hemiarthroplasty acutely for proximal humerus fractures frequently experience loss of function, with residual stiffness and weakness compared with the contralateral shoulder, [103] although pain relief may be satisfactory [43, 45, 110, 112-117]. This is likely magnified by the fact that a large portion of this patient population could be more active and functional at baseline than patients who receive shoulder arthroplasty for degenerative arthritis.

On the other end of the spectrum, elderly patients who sustain proximal humerus fractures in falls may be less functional overall, thus less capable of participating in aggressive rehabilitation, leading to poor functional results after hemiarthroplasty [110, 112, 119, 123, 124].

Technical considerations when performing hemiarthroplasty include component position and tuberosity reconstruction [125, 126]. These issues are problematic when faced with metaphyseal comminution or bone loss and either very large or comminuted greater tuberosity fragments. Prostheses specifically designed for fracture treatment can address these concerns. These have multiple options for suture attachment and can accommodate a large greater tuberosity fragment without causing impingement. Application of autogenous bone graft from the humeral head to the area between the greater and lesser tuberosities may improve healing of the tuberosities. Care should be taken to keep cement out of this region because it would interfere with bone healing.

One recent study reviewed 71 patients treated acutely with hemiarthroplasty for proximal humerus fractures [125]. Their mean age was 66 years, and indications for surgery included displaced 4-part and 3-part fractures, head-split fractures, and anatomic neck fractures. Of the patients, 93% reported no or slight pain and were satisfied. Malreduction of the greater tuberosity was the most common complication, occurring in 22% of cases. Overall, patient function was most affected by the quality of the reconstruction of the greater tuberosity [125]. This is consistent with other studies [43, 110, 116, 124, 127, 128]. Additional patient factors that contribute to successful outcome include younger age, strong functional status at baseline, and no associated neurologic deficits [43]. Careful attention to component position and tuberosity reconstruction during surgery will reduce complications [126]. By coupling this with an appropriately aggressive rehabilitation plan, patient satisfaction and function will be maximized [43, 45, 111, 125, 127].

**Summary**

Proximal humerus fracture management is constantly evolving, particularly in light of improved understanding of proximal humerus fracture characteristics and innovations in surgical technique and technology. The orthopaedic surgeon should approach proximal humerus fractures on a case-by-case basis and tailor treatment according to patient and fracture characteristics. Treatment decision-making should include assessing the vascular status of the humeral head, determining the optimal fixation constructs, and implementing local adjuvants as needed to enhance anatomic fracture
healing. The likelihood of humeral head ischemia is established using the AO/ASIF classification and Hertel's radiographic criteria. Fractures with AO/ASIF type C pattern, metaphyseal extension 2 mm are associated with high probability of osteonecrosis and probably are best treated with hemiarthroplasty. When fixation is required, fracture pattern and cortical thickness should guide the treatment approach and fixation technique. AO/ASIF type A fractures are typically treated with sling immobilization. Proximal humerus fractures with surgical neck translation >66% or tuberosity displacement >5 mm may be treated with transosseous suture fixation (cortex 4 mm). For multifragment fractures, locked compression plating creates a stable construct with preservation of the periosteal blood supply. Calcium phosphate cement, demineralized bone matrix, and allografts are important local adjuvants that may improve rates of osseous union and minimize malunion. So, humeral head preservation and osteosynthesis are being increasingly favored.

References


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