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Proximal Humeral Fractures: Diagnosis and Management

Kirk L. Wong, M.D.[1] and Gerald R. Williams, Jr., M.D.[2]

From the Shoulder and Elbow Service, Department of Orthopaedic Surgery, University of Pennsylvania School of Medicine, [1]Resident, Department of Orthopaedic Surgery, [2]Associate Professor, Department of Orthopaedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, PA.

Address correspondence to: Gerald R. Williams, Jr., M.D., Penn Musculoskeletal Institute, 1 Cupp Pavillion, Presbyterian Hospital 39th and Market Streets, PA 19104.

Abstract: The diagnosis and management of fractures of the proximal humerus continue to provide a formidable challenge to treating physicians. In spite of recent data which questions the reliability of both the Neer and AO classification systems, the Neer system is still widely used for pretreatment classification as well as surgical planning in patients selected for operative treatment. Accurate diagnosis is most often determined with history, physical examination, and routine radiography. In some cases, computed tomography (CT scan) is helpful in determining tuberosity displacement, intra-articular extension (i.e., head-splitting fractures), concomitant glenoid fracture, and surgical approach. Angiography is indicated in cases of suspected vascular injury. Electromyography is not useful in the acute setting, but may be used in the subacute setting for diagnosis and documentation of reinnervation in cases of suspected nerve injury.

Many surgical techniques have been described for displaced fractures. Currently the most popular techniques include: closed reduction and percutaneous pinning for selected two-part surgical neck fractures; open reduction, and internal fixation with a blade plate or combined intramedullary Ender's rods and figure-of-eight suture or wire in selected two-part surgical neck fractures; open reduction and internal fixation with interfragmentary sutures or wires in isolated tuberosity or three-part fractures; and hemiarthroplasty in most four-part and selected three-part fractures. Results of surgical management are inconsistent and depend on fracture pattern, surgical technique, and post-operative rehabilitation. Complications include neurovascular injury, avascular necrosis, nonunion, malunion, stiffness, and post-traumatic arthritis.

Introduction

Fractures of the proximal humerus are not uncommon, especially in older age groups. They have been reported to account for 4% to 5% of all fractures [20,30,36]. Eighty-five percent of these fractures are minimally or non-displaced and are effectively treated symptomatically with immobilization followed by early motion [2,27,32,33]. The remaining 15% of fractures are displaced and provide the orthopaedist with a therapeutic challenge. Fracture of the proximal humerus is still the unsolved fracture in many ways. Disagreement exists with regard to reliability of classification systems [1,38,39]. The indications for surgical management continue to be modified. Fixation techniques are myriad and none is ideal for all cases. Furthermore, in elderly patients with osteoporosis, poor bone quality as a mitigating factor is often present. This article will review our current practice with regard to the diagnosis and management of proximal humeral fractures.

Classification

In 1896 Kocher [26] developed a classification system based on the anatomical level of the fracture---anatomical neck, metaphyseal region, and surgical neck. This simple scheme is easily understood but does not apply to many complex fracture patterns commonly encountered.

In 1934 Codman [7] proposed the four segment classification concept. He recognized that fractures of the proximal humerus typically produced a combination of four possible fragments---the articular surface, the humeral shaft, the greater tuberosity, and the lesser tuberosity. He hypothesized that the fracture lines followed the remnant of the old epiphyseal plate, the epiphyseal scar. He concluded that all fractures were some combination of these different fracture fragments.

The four-part classification reported by Neer [32,33] in 1970 represents a refinement of Codman's four-segment classification that incorporates the concepts of displacement and vascular isolation of articular segment. This classification was the first comprehensive system that related the anatomy and biomechanical forces resulting in the displacement of fracture fragments to diagnosis and treatment [2,32,33]. Regardless of the number of fracture lines present, a proximal humerus fracture is considered to be nondisplaced by Neer's criteria when plain radiographs reveal less than 1 centimeter of displacement and 45 degrees of angulation of any one fragment with respect to all others. Two-part fractures may involve the anatomic neck, surgical neck, greater tuberosity, or lesser tuberosity and occur when one fragment is displaced at least one centimeter or angulated 45 degrees or more with respect to any of the remaining three fragments. Three-part fractures result from a displaced fracture of the surgical neck in combination with either a displaced greater tuberosity or lesser tuberosity fracture. Four-part fractures result from displaced fractures of the surgical neck and both tuberosities. Any fracture pattern may occur in combination with a glenohumeral dislocation. Humeral head indentation fractures and head-splitting fractures represent special cases that do not otherwise fit the four-part classification system [2]. The Neer four-part classification is summarized in Figure 1.

Figure 1

Fig. 1. The Neer classification system is currently the most widely used system. It is based upon accurate identification of each of four potential fracture fragments: the articular head, lesser tuberosity, greater tuberosity, and shaft. (Reprinted with permission from Bigliani LU: Fractures of the proximal humerus. In: Rockwood CA and Matsen FA (eds.). *The Shoulder*. Philadelphia, W.B. Saunders, 1990, pp. 278--334).

The AO/ASIF classification emphasizes the vascular supply to the articular segments [23]. The system is divided into three categories, according to the severity of injury and the likelihood of avascular necrosis. Type A fractures are the least severe with no vascular isolation of the articular segment, and the risk of avascular necrosis is small. Type B fractures represent a more severe fracture with partial isolation of the articular segment with a low risk of avascular necrosis. Type C fractures is the most severe with total vascular isolation of the articular segment and a high risk of avascular necrosis. Furthermore, each alphabetical group is subgrouped numerically, with higher numbers generally reflecting greater severity. The AO/ASIF classification system has not enjoyed widespread popularity.

Recently the interobserver reliability and intraobserver reproducibility of classification of proximal humerus fractures have been questioned. Sidor et al. [38] reported only a "fair" response for inter- and intraobserver parameters with the Neer classification (kappa equal to 0.5 and 0.66, respectively. Although the level of expertise and experience did not affect reliability, it was a significant factor in reproducibility, with a shoulder specialist achieving the highest correlation coefficient. Siebenrock et al. [39] found a mean kappa value of 0.4 (poor) and 0.6 (fair) for interobserver and intraobserver reliability respectively using the Neer classification. They also examined the AO/ASIF classification system and found similar results with a kappa value of 0.53 for interobserver reliability and 0.58 for intra-observer reproducibility. They pointed out that the main difficulties in fracture classification were assessment of the lesser tuberosity and determination of the exact amount of displacement of the fragments. This suggests that in both classification systems, the problem may be the tool (i.e., radiographs) rather than the classification system.

Bernstein and colleagues [1] investigated the effect on inter-observer reproducibility and intra-observer reliability of computed tomography (CT scans). The mean kappa coefficient for intra-observer reliability was 0.64 when the fractures were assessed with radiographs alone and 0.72 when they were assessed with radiographs and CT scans. The mean kappa coefficients for inter-observer reproducibility were 0.52 and 0.50, respectively. The addition of CT scans was associated with a slight increase in intra-observer reliability but no increase in inter-observer reproducibility.

Despite the reported difficulties of reliability, the Neer classification is still widely used by most surgeons for the diagnosis and treatment of proximal humerus fractures. It provides a rationale for surgical management and allows the formulation of a surgical plan based on the known fracture fragments and associated rotator cuff attachments. It will remain a useful tool until a more reliable classification is identified.

Diagnosis

Fractures of the proximal humerus occur in all segments of the population. The vast majority of proximal humerus fractures result from a fall from a standing height. They may occur as an isolated injury as seen in the older population or as part of a polytrauma, which is more common in the younger population [36]. Factors to be considered include mechanism of injury, the amount of energy required for the injury to occur, and the underlying medical condition of the patient. Regardless of age or mechanism of injury, associated injuries may occur and must be identified. In most cases, physical examination and plain radiography will provide a diagnosis and treatment plan. CT may provide additional information in selected cases but should not be a substitute for adequate routine radiographs. Angiography is indicated when vascular injury is suspected. Electromyography is not useful in the acute setting but may be used subacutely to fully characterize any neurologic injury and to document recovery.

Physical examination

Patients presenting immediately after injury typically experience significant shoulder pain and may not volunteer information regarding other anatomic regions that may have also been injured. Therefore, it is important not only to inquire about other areas of discomfort but also to palpate all four extremities and move all apparently uninjured joints. Palpation of the ipsilateral hemithorax and auscultation of both lung fields should be considered in suspected cases of concomitant rib fracture, particularly if the possibility of surgical intervention is being entertained for definitive management of the proximal humerus fracture.

Swelling of the shoulder and arm is usually present immediately. However, ecchymosis will not appear for 24 to 48 hours after injury. Palpation of the proximal humerus will elicit severe pain. Caution should be exercised when attempting to move the injured shoulder in cases of suspected proximal humerus fracture to avoid further injury.

Peripheral neurological examination should be performed in all patients with suspected proximal humerus fracture. Sensory examination on the lateral aspect of the proximal arm is unreliable because of overlap in the distribution of the axillary, supraclavicular, and radial nerves [3]. Therefore, motor function should be verified in all major peripheral nerves of the injured arm. This can be accomplished by asking the patient to extend the thumb interphalangeal joint (radial nerve), make a fist (median nerve), spread the fingers apart (ulnar nerve), and flex the elbow (musculocutaneous nerve). Motor function of the axillary nerve can be tested by asking the patient to attempt shoulder abduction while the deltoid muscle belly is palpated for contractions. The most common nerve injury patterns associated with fracture or dislocation of the proximal humerus are isolated axillary nerve and mixed brachial plexus [3,40].

In the absence of complete laceration of the axillary artery, physical findings on vascular examination may be very subtle (Figure 2). Absence or asymmetry of radial pulse should raise the possibility of an injury to the axillary artery. Viability of the distal limb is usually preserved as a result of rich anastomoses between the circumflex scapular artery (branches of the third part of the axillary artery), and dorsal scapular artery (the third part of the subclavian artery). If vascular injury is suspected, an angiogram is indicated.

Figure 2

Figure 2

Fig. 2. (**A, B**): Axillary radiograph (**A**) and anteroposterior projection of an angiogram (**B**) obtained on a 70-year-old female who fell at home and fractured her proximal humerus. She presented with a complete brachial plexus injury. Her fingers were pink and warm. The only indication of her vascular injury was a decrease in the radial pulse which was attainable by ultrasound. Note the severe medial displacement of the shaft. There was an intimal lesion just proximal to the anterior humeral circumflex origin, which had been avulsed.

Radiographic examination

Accurate radiographic assessment of the fracture configuration is essential to diagnosis and treatment. This is best accomplished with anteroposterior and lateral (Y-view) radiographs in the scapular plane and an axillary view. In 1970, Neer [33] referred to this series of radiographs as the "trauma series" and it is still the single most important diagnostic tool when evaluating proximal humerus fractures. The axillary view is essential for evaluating the degree of tuberosity displacement, the presence of glenoid surface defect, and the presence of dislocation.

If the patient cannot comply with the positioning required to obtain an axillary view, the velpeau axillary view can be used [4]. The velpeau lateral can be obtained without removing the sling (Figure 3).

Figure 3

Fig. 3. The velpeau lateral can be taken without removing the sling and is useful in patients who cannot be positioned to obtain a standard axillary view. (Reprinted with permission from Bigliani L, Flatow E, Pollock R: Fractures of the Proximal Humerus. In: Rockwood C, Green D, Bucholz R, et al. (eds.). *Rockwood and Green's Fractures in Adults.* Philadelphia, Lippincott-Raven Publishers, pp. 1055--1107, 1996).

CT scan

CT is indicated in selected cases for quantitating the amount of tuberosity displacement, the size of humeral head indentation fractures, the extent of articular involvement in head-splitting fractures, and the displacement or extent of comminution of associated glenoid fractures (Figure 4). When a CT scan is indicated, 2-mm cuts should be obtained. Three-dimensional reconstruction is not routinely required but could be helpful in complex fracture configurations or malunions.

Figure 4

Figure 4

Fig. 4. (**A, B**): Anteroposterior radiograph (**A**) demonstrating displacement of the humeral shaft. CT scan (**B**) confirms greater tuberosity displacement. Therefore, this is a three-part fracture.

Other tests

As previously discussed, angiography is indicated when there is an increased level of suspicion. Asymmetry or absent pulses are not the only indication. Some patients can have seemingly normal pulses in light of an axillary artery injury. Consideration should also be given to degree of fracture displacement, amount of energy at time of injury, swelling, and neural injury. Vascular injuries most commonly occur in the third part of the axillary artery where the vessel is tethered to the humerus by the anterior and posterior humeral circumflex branches [2,40]. When vascular damage is present, it is often associated with severe medial shaft displacement through a surgical neck fracture (Figure 2).

Electromyography immediately after nerve injury is not likely to provide information that will alter initial management. As mentioned, it is most appropriate in the subacute setting (i.e., 3 weeks) for confirmation or detailed characterization of nerve injuries suspected clinically. Electromyography may also be used to document the progress of reinnervation.

Treatment

Non-operative

Eighty-five percent of proximal humeral fractures are nondisplaced or minimally displaced [2,32,33]. These fractures can be managed non-surgically, by immobilizing the arm in a sling for comfort and instituting early range of motion exercises when pain permits. Patients with medical illnessess that preclude them from surgery should also be treated conservatively. In general, pendulum exercises and gentle isometric strengthening of biceps and triceps to compress fracture fragments are started after one week of immobilization. After 3 to 4 weeks, supine passive flexion and passive external rotation exercises may be added. Overhead pulley are started at 4--5 weeks, followed by stretching and strengthening at 6--8 weeks [2,27].

Operative

In the absence of medical contraindications, displaced fractures of the proximal humerus should be treated operatively. However, the results of surgical management are variable and dependent on many factors that include fracture pattern, quality of the surgical reduction, stability of fixation, patient age, bone quality, patient motivation and reliability, experience of the surgeon, and post-operative rehabilitation. Many methods of fixation of proximal humerus fractures have been described and discussion of all reported methods is beyond the scope of this article [8--10,17,18,21,28,29,34,35,41,42]. The following sections will detail our current preferred methods of surgical management of specific fractures.

Two-part surgical neck fractures. In two-part surgical neck fractures, both tuberosities are attached to the head which often remains in a neutral or slightly abducted position. The shaft is usually displaced medially and anteriorly by the pectoralis major. Preferred treatment options include closed reduction and percutaneous pinning, open reduction and stabilization with a blade-plate, and open reduction and stabilization with intramedullary Ender's rods combined with inter-fragmentary sutures [5,10,21,22,24,37].

Closed reduction with percutaneous pinning is indicated in patients with good bone quality and non-comminuted or minimally comminuted fractures that can be reduced adequately by closed means. The patient is positioned supine on a radiolucent operating table with the injured arm and shoulder unsupported lateral to the edge of the table. The image intensifier is positioned above the patient's head and parallel to the edge of the table (Figure 5). Closed reduction is performed and verified with fluoroscopy. If the reduction is adequate, an assistant maintains the position with a posteriorly directed force on the humeral shaft while the surgeon places two to three terminally threaded or smooth pins from the shaft into the head. If terminally threaded pins are used, they should be inserted through a protective sheath. Normal humeral retroversion places the center of the humeral head posterior to the humeral shaft. Therefore, pin placement is facilitated by using an anterolateral entry point and directing the pin posteromedially (Figure 5). The pins are cut below the skin and pendulum exercises are begun on postoperative day one. After pin removal 3--4 weeks post-operatively, supine passive flexion and external rotation exercises are added. An overhead pulley is initiated at 5--6 weeks post-operatively. Stretching and strengthening are added at 6--8 weeks. If the patient has been selected appropriately, an anatomic result is the rule rather than the exception (Figure 6).

Figure 5

Fig. 5. During closed reduction and percutaneous pinning of two-part surgical neck fractures, the image intensifier is positioned superiorly, an assistant maintains the position of the reduced fragments, and the surgeon places two to three pins from the shaft into the head. Note that the entry point for the pins is anterolateral, rather than directly lateral, and that the pins are directed posteromedially toward the center of the humeral head.

Figure 6

Fig. 6. (**A--D**): Pre-operative anteroposterior (**A**) and axillary (**B**) radiographs of an 18-year-old college student who was hit by a car. The underlying bone quality was excellent, the fracture was minimally comminuted, and the closed reduction was adequate. Therefore, the fracture was treated with closed reduction and percutaneous pinning (**C**). The pins were removed 3 weeks post-operatively and the fracture healed uneventfully (**D**).

Open reduction and internal fixation is indicated in fractures with inadequate closed reduction, severe comminution, or poor bone quality. The fracture is approached anteriorly through an extended deltopectoral incision. We prefer to use blade plate fixation, except in cases involving extreme osteoporosis of the humeral shaft, because it exploits the only two places in the proximal humerus with reasonable bone quality---the subchondral bone and the shaft (Figure 7). In addition, insertion of the blade-plate spares the rotator cuff insertion. Intramedullary Ender's rods in combination with inter-fragmentary sutures are used when the humeral shaft is so osteoporotic that adequate bicortical fixation is doubtful.

Figure 7

Figure 7

Fig. 7. (**A, B**): Blade-plate fixation exploits the two areas of the proximal humerus with reasonable bone quality-the cortex of the shaft and the subchondral bone of the articular surface. This nonunion (**A**), which had been previously operated, was stabilized well enough to allow early mobilization with a 90-degree blade-plate (**B**).

Post-operative rehabilitation after stabilization with a blade plate involves immediate pendulum, supine passive flexion, and passive external rotation exercises. An overhead pulley is added at 3 weeks. Stretching and strengthening are initiated at 6--8 weeks. The post-operative regimen after intra-medullary stabilization is similar except that rotational exercises are witheld until 2--3 weeks post-operatively because of the potentially poor rotational stability of the fixation construct [44].

Two-part isolated tuberosity fractures. Closed reduction of two-part greater tuberosity fractures is difficult because the fragment is pulled superiorly and posteriorly by the attached rotator cuff muscles. Open reduction of the fragment can be done through a deltopectoral approach or through a superior, deltoid splitting approach [12,18]. We prefer the superior approach in most cases. However, we carry the deltoid split onto the acromion and subperiosteally reflect the anterior deltoid origin in a fashion similar to rotator cuff repair. Distal exposure should be limited to 4--5 cm from the lateral edge of the acromion because of the risk of axillary nerve injury [12]. Fixation is achieved with heavy non-absorbable interfragmentary sutures incorporating the rotator cuff combined with repair of rotator interval or rotator cuff tear if present. A deltopectoral exposure is used if there is a long inferior spike on the greater tuberosity. Exposure of the inferior-most portion of the fragment through a superior approach could jeopardize the axillary nerve. When approaching the greater tuberosity through a deltopectoral incision, posterior exposure is greatly facilitated by adbuction of the arm to relax the deltoid.

Post-operatively, we prefer to protect the fixation with an abduction pillow or brace. The primary purpose of this protection is to prevent maximal internal rotation. Pendulum exercises are begun on the first postoperative day. Supine passive flexion and external rotation are added 2 weeks post-operatively. An overhead pulley is initiated 4 weeks post-operatively. Stretching and strengthening are added 6--8 weeks post-operatively.

Isolated lesser tuberosity fractures are rare. The displaced tuberosity in the absence of associated dislocation rarely results in a functional deficit [16]. Open reduction and internal fixation is required when the fragment is large and blocks medial rotation [2]. The approach is through the deltopectoral interval, and interfragmentary sutures are used to secure the fragments. Rehabilitation after operative fixation consist of pendulum exercises begun on the first or second post-operative day, supine passive flexion and passive external rotation at 2--4 weeks, overhead pulley at 6 weeks, and stretching and strengthening at 8 weeks.

Three-part fractures. Closed reduction and percutaneous pinning of three-part fractures has been reported [22,34]. However, these injuries are difficult to manage closed and are usually best managed with open reduction and internal fixation or, rarely, prosthetic hemi-arthroplasty. A deltopectoral approach allows adequate exposure for reduction and fixation. In the majority of cases, the use of interfragmentary sutures are adequate because of an intact posteromedial periosteal hinge [10,17]. It is important to first secure the tuberosity to the head followed by suturing the head and tuberosity to the shaft. If stability between the head fragment and shaft is inadequate, one may supplement with intramedullary Ender's rods or blade plate (Figure 8) [10]. Rehabilitation consists of sling immobilization for 1 week, pendulum exercises at 1--2 weeks, supine passive flexion and external rotation at 2--4 weeks, overhead pulley at 6--8 weeks, and stretching and strengthening at 8--10 weeks.

Figure 8

Fig. 8. (**A--C**): Pre-operative (**A**), 3-month post-operative (**B**) anteroposterior radiographs and clinical result (**C**) of a three-part fracture (surgical and greater tuberosity) treated with interfragmentary sutures through a deltopectoral approach (courtesy of Charles A. Rockwood, Jr. M.D.).

Four-part fractures. Eighty to ninety percent of four-part fractures result in avascular necrosis of the humeral head [2,32,33]. Hemiarthroplasty is most often the procedure of choice [2,32,33]. In young active patients in whom the articular segment is of adequate size and quality, open reduction and internal fixation may be attempted. A deltopectoral approach is used, with preservation of the deltoid origin and insertion. Attention to several technical considerations will contribute to a successful result [11]. Existing fracture lines should be exploited rather than creating new ones. The prosthesis should be cemented to ensure restoration of humeral height and appropriate version. The tuberosities should be pulled beyond the level of the prosthetic head and fixed to each other and to the humeral shaft (Figure 9). The goal is to achieve union of the tuberosities to the shaft and to restore rotator cuff function. With secure tuberosity fixation, immediate pendulum exercises should be instituted, followed by supine passive flexion and passive external rotation at 1--2 weeks, overhead pulley at 4-6 weeks, and stretching and strengthening at 6--8 weeks.

Figure 9

Fig. 9. (**A--D**): Pre-operative CT scan (**A**) demonstrating a four-part fracture with complete isolation of the articular segment. Post-operative anteroposterior (**B**) and axillary radiographs (**C**) depict anatomic healing of the tuberosities. This resulted in an excellent clinical outcome (**D**).

Results

Non-displaced fractures

Traditionally, the results of non-operative management of non-displaced proximal humerus fractures have been thought to be excellent [2,19,23]. However, Koval and colleagues [27] recently reported only 77% good or excellent results in a large series of patients with non-displaced fractures treated non-operatively. Most of the functional deficits were the result of loss of motion. Patients who were started on a formal physical therapy program within 14 days of injury had significantly better results.

Two part surgical neck fracture

Closed treatment of two-part surgical neck fracture is associated with a satisfactory or excellent outcome if closed reduction can be achieved and maintained [6]. Jaberg et al. [22] reviewed 29 patients with two-part surgical neck fractures treated with closed reduction and percutaneous pinning and found 18 patients (62%) with good or excellent results using an 18-point scale that combined subjective and objective criteria. The fair results in eight patients were due predominantly to the patient's subjective symptoms and loss of rotation, which may have been related to the post-operative rehabilitation protocol.

Cuomo et al. [10] reported good or excellent results in 10 (71%) of 14 patients treated with open reduction and internal fixation using interfragmentary sutures with the addition of Ender's rods if surgical neck comminution were present. The average range of motion was 145 degrees of elevation, 43 degrees of external rotation and internal rotation with the hand reaching the 11th thoracic vertebra.

The results after blade-plate fixation have been sparsely reported. In some cases, the reported results included non-unions, osteotomies, and fractures [21,24,37]. However, the reported rates of good and excellent results have been equal to or better than those reported for other techniques of fixation.

Two-part tuberosity fracture

In the absence of dislocation, two-part greater tuberosity fractures had good results in only 56% of patients when treated by closed technique; however, 100% of fracture-dislocations had poor results with closed treatment [6]. Displacement of the greater tuberosity has been associated with poor results if it remained displaced by more than 1 cm [31]. Flatow et al. [12] reported excellent and satisfactory results in all 12 patients with two-part greater tuberosity fracture treated with open reduction and internal fixation using non-absorbable sutures.

Three-part fractures

Closed treatment of three-part fracture is associated with a poor functional outcome [2,6,24,25,30,32]. Cuomo et al. [10] reported good or excellent results in all eight patients treated with open reduction and internal fixation using interfragmentary sutures with the addition of Enders rods if surgical neck comminution were present. Hawkins et al. [17] examined the functional result, range of motion, and level of pain in 14 patients with three-part proximal humerus fracture treated with tension band wiring and found good functional results in the majority of patients. Futhermore, in all but three patients, either relief of pain was complete or pain occurred only occasionally. The average elevation achieved was 126 degrees, active external rotation of 29 degrees, and internal rotation to L2 vertebrae. There were no cases of nonunion or significant malunion. In two patients avascular necrosis developed, but only one of them required hemi-arthroplasty.

In cases when there is significant osteoporosis and the quality of bone is poor, some authors recommend immediate prosthetic head replacement [32,43]. Tanner and Cofield [43] analyzed 16 patients with acute three- and four-part fractures treated with hemi-arthroplasty and found pain relief in all of the 16 shoulders. However, the return of function was less predictable and dependent on the security of tuberosity-muscle cuff repair, sufficient protection after surgery, and long-term rehabilitation. Goldman et al.[14] studied 22 patients with three- and four-part fractures treated with prosthetic replacement and found 73% of patients with slight or no pain. Active forward elevation averaged 107 degrees, external rotation averaged 31 degrees, and the average internal rotation was to L2 vertebrae.

Four-part fractures

In the treatment of four-part fractures, less than satisfactory results are obtained with either closed reduction or open reduction and internal fixation [32,42]. Before prosthetic replacement, treatment of these injuries yielded poor results [24,25,38,42]. Neer [32] and Green et al. [15,32] reported nearly 90% satisfactory results with prosthetic replacement. They also demonstrated that although the functional results vary, the operation predictably prevents the development of a painful shoulder. Other authors have reported similar findings [11,14]. Frich et al. [13] and Tanner et al. [43] have shown less satisfactory results with late prosthetic replacement after previous failed open reduction and internal fixation secondary to malunion and fixed retraction of the tuberosities.

Conclusions

The majority of proximal humerus fractures are non-displaced by Neer's criteria. Nonoperative management will produce a high percentage of acceptable results, provided that rehabilitation exercises are instituted within 14 days of injury. The results of surgical management of displaced fractures are variable and dependent on fracture type, bone quality, quality of the surgical reduction and fixation, surgeon experience, and patient compliance. Currently, we prefer closed reduction and percutaneous pinning in two-part surgical neck fractures with good bone quality, little or no comminution, and an acceptable closed reduction. When open reduction is indicated, blade-plate fixation is an excellent choice, except when cortical osteoporosis precludes good bicortical fixation in the shaft. Under these circumstances, intramedullary Ender's rods combined with inter-fragmentary sutures are used. Isolated two-part greater tuberosity fractures are managed with inter-fragmentary sutures through a superior deltoid "splitting" approach. If distal exposure beyond 4--5 cm is required, a deltopectoral approach is used. Lesser tuberosity fractures are stabilized with inter-fragmentary sutures through a deltopectoral approach. Most three-part fractures are amenable to inter-fragmentary sutures with occasional supplemental Ender's rods or blade-plate fixation. Hemiarthroplasty is performed in most four-part fractures and some three-part fractures with poor bone quality or extensive comminution. The goal of all surgical management is adequate stability, so early (within 7--10 days) rehabilitation can be initiated.

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