Open Reduction Internal Fixation Four-part Proximal Humerus Fractures

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I. Operative Indications

Four-part fractures typically occur in elderly patients with poor bone quality and are often not amenable to osteosynthesis. Avascular necrosis with subsequent collapse is common (1,2). Moreover, the results of hemiarthroplasty in this patient population are better than the results of operative fracture stabilization (1,3). Therefore, the optimal treatment for most four-part proximal humerus fractures is prosthetic replacement.

Classical four-part fractures may also occur in young patients as the result of high-energy trauma. These patients often have very active lifestyles that are not compatible with prosthetic management. Therefore, open reduction and internal fixation of proximal humerus fractures with four-part displacement is considered in patients under the age of forty. However, patient selection is critical to success. One must be able to obtain stable enough fixation to allow passive mobilization within the first post-operative week and the patient must be reliable enough to cooperate with post-operative rehabilitation.

Valgus-impacted four-part fractures represent a special type of four-part fracture. They often are not comminuted and have a much lower incidence of avascular necrosis than classical four-part fractures because of arterial vessels that enter the head through the intact inferomedial periosteum (4). Consequently, operative stabilization is the preferred treatment of valgus-impacted four-part fractures, except in patients whose bone quality is too poor to obtain stable fixation. Surgical management of acute valgus-impacted four-part fractures commonly involves closed or percutaneous reduction and percutaneous stabilization with pins and/or screws. This technique is predicated on the ability of the surgeon to obtain adequate reduction and fixation using closed or percutaneous means; it is covered in chapter two of this book. The following chapter discusses open reduction and internal fixation of acute valgus-impacted four-part fractures that are not amenable to closed or percutaneous methods, subacute (greater than two weeks) valgus-impacted four-part fractures, and classical four-part fractures in patients under the age of forty.

II. Pre-operative Planning

Pre-operative planning begins with an accurate diagnosis of the fracture and all other associated injuries. As mentioned above, four-part fractures in patients under the age of forty are often the result of high-energy trauma. Therefore, physical examination is directed toward identifying more serious injuries such as chest or rib injuries, intra-abdominal injuries, or intra-cranial injuries. In addition, a musculoskeletal survey should be performed to identify spine, pelvic, or other long bone fractures. Motor function should be verified in all five (axillary, musculocutaneous, radial, median, and ulnar) major peripheral nerve distributions of the injured upper extremity, as sensory examination around the shoulder is unreliable. A high index of suspicion must be maintained with regard to associated axillary arterial injury because of the extensive collateral circulation between the third part of the subclavian artery and the third part of the axillary artery (5).

The decision to proceed with open reduction and internal fixation of a four-part proximal humerus fracture is not only based upon patient age and activity level but also on degree of comminution and integrity of the articular segment. If the humeral head is fractured into two or more pieces, anatomic reduction and stable fixation may not be possible. The importance of the trauma series of radiographs in accurately classifying the fracture has been covered in chapter one of this book and cannot be overemphasized. If adequate assessment of the fracture cannot be obtained with plain radiographs, computed tomographic (CT) scanning is indicated. Three-dimensional reconstruction of the axial CT images is not mandatory but may aide in determining the displacement and orientation of the head fragment. In the vast majority of cases, however, the fracture can be adequately characterized and a treatment plan can be formulated on the basis of the trauma series alone. A CT scan should not be a substitute for poor radiographs.

Multiple fixation methods have been described for osteosynthesis of proximal humerus fractures. These methods include interfragmentary sutures or wires, tension band wires, pins, screws, plates, blade-plates, and intramedullary rods. None of these methods is ideal for all fractures. Therefore, the surgeon must be familiar with more than one method and plan to have the appropriate instruments and/or implants available in the operating room. From a practical standpoint, one should have heavy nonabsorbable suture material, wire (18 gauge or bigger), multiple sized kirschner wires, terminally threaded 2.5 mm pins (guidewires from the 6.5 mm cannulated screw set), Ender's rods, and a plate/blade-plate and screw fixation system. A small (4.0-4.5 mm) cannulated screw system may facilitate the fixation process but is not essential.

Impaction or actual partial loss of the metaphyseal cancelleous bone of the proximal humerus is common in four-part fractures, particularly those involving valgus-impaction of the humeral head. Once the head and tuberosities have been returned to their anatomic positions, deficiency of the metaphyseal bone may exist. Although reconstitution of this defect is not required in all cases, pre-operative planning must include the potential for use of cancelleous bone graft or other bone substitutes. A detailed discussion of the risks and benefits of cancelleous autograft, cancelleous allograft, and the multitude of bone substitutes available is beyond the scope of this chapter. However, the possible need for these materials and the potential ramifications of their use should be discussed with the patient and their family pre-operatively. Moreover, arrangements should be made with the operating room to have cancelleous allograft bone chips or whatever other bone substitute has been decided upon available.

Fracture reduction is often difficult to visualize intraoperatively. The rotator cuff inserts extensively on the greater and lesser tuberosities and makes visualization of the head and other fracture fragments difficult. Although incision of the rotator interval may improve visualization of the joint and articular surface of the head fragment, intra-operative assessment of the reduction may still be difficult. Therefore, pre-operative arrangements should be made for intraoperative use of a C-arm and image intensifier. If a C-arm is not available, intraoperative plain radiographs may be obtained.

Operative stabilization of any four-part proximal humerus fracture should never be undertaken without the ability to convert to a hemiarthroplasty intraoperatively. The surgeon may find that the degree of comminution and severity of the injury were underestimated preoperatively and that stable fixation is not possible. This possibility should have been discussed with the patient and his or her family preoperatively. Moreover, a shoulder arthroplasty instrument set and a complete set of implants should be available in the operating room.

III. Operative Approaches

A. Valgus-impacted four-part fractures

1. Acute valgus-impacted fracture

As mentioned previously, the majority of acute valgus-impacted four-part fractures are amenable to closed or percutaneous reduction and percutaneous fixation. Although this technique is discussed in detail in chapter two of this book, certain aspects of the technique are emphasized here because they are also relevant to open reduction and internal fixation. The musculo-periosteal sleeve surrounding the tuberosities is intact. Therefore, when tension in the sleeve is re-established by reducing the head, the tuberosities reduce easily. The head is maintained in its reduced position with retrograde 2.5 mm terminally threaded pins inserted through the anterolateral shaft into the head. The tuberosities are stabilized either with 2.5.mm terminally threaded pins or cannulated screws placed percutaneously.

If the head cannot be reduced percutaneously, open reduction and internal fixation is indicated. Both deltopectoral and deltoid-splitting approaches have been described (6). The lateral, deltoid-splitting approach offers the advantage of better visualization of the greater tuberosity fracture line. However, this approach cannot be extended more than 4.5-5.0 cm distal to the lateral margin of the acromion without damaging the axillary nerve. Therefore, it is not as versatile as the deltopectoral approach.

Once the fracture is exposed, two basic methods of reduction and stabilization have been described. One method involves extensive dissection of the fracture fragments, direct fracture reduction, and plate/screw fixation. The other method involves minimal surgical dissection, indirect reduction of the tuberosities by reducing the head with an elevator placed through the gap between the tuberosities, and minimal internal fixation using a combination of terminally threaded pins, screws, and interfragmentary sutures. Cancelleous bone grafting has been described with both methods (6,7,8).

2. Subacute (greater than two weeks) valgus impacted fractures

Valgus-impacted four-part fractures begin to heal quickly because of the stability imparted by the impaction and the type of bone through which they occur. Consequently, fractures that are more than two weeks old will be difficult to reduce percutaneously without applying significant force to the head fragment. Maintaining the inferomedial periosteal vessels is important in minimizing the risk of avascular necrosis. The reduction is probably more safely obtained through open means. The approaches are the same as in the acute situation, as are the reduction and fixation options. The use of cancelleous bone graft or bone substitute is more likely in the subacute setting because there is a greater tendency for the head to collapse into varus. This may be the result of scarring and early contracture of the musculo-periosteal sleeve.

B. Classical four-part fractures

Open reduction and internal fixation of standard four-part fractures is performed through a deltopectoral approach. Multiple methods of fixation have been described. These methods fall under three general categories: 1. intramedullary, 2. extramedullary—plate osteosynthesis, and 3. extramedullary—minimal osteosynthesis.

Intramedullary devices may be rigid or flexible. Fixation of the proximal fracture fragments is typically obtained with screws that pass through the nail or wires passed in a tension band configuration. Mouradian used a modification of the Zickel nail used for supracondylar femur fractures to treat a variety of proximal humerus fractures , seven of which were four-part fractures (9). Darder, et al used intramedullary K-wires reinforced with a tension band wire in a series of 33 displaced four-part fractures. The K-wires were passed through the tuberosities and down the shaft and the tension band was passed between the tuberosity K-wires to the shaft (10).

Plates have also been advocated in the treatment of true four-part fractures. Techniques have been described for T-plates (11,12), cloverleaf plates (13,14), and blade-plates (15). The two major disadvantages of plate fixation are the soft-tissue dissection required to place the plate and impingement of the upper margin of the plate against the acromion. Esser reported the use of a modified clover-leaf plate in the treatment of ten four-part fractures. The plate was modified by removing the superior and anterior portions of the plate (13). These modifications may help to avoid impingement and injury to the ascending branch of the anterior humeral circumflex artery, the terminal branch of which (arcuate artery) supplies the major portion of the humeral head blood supply. The advantages of the cloverleaf plate are the ability to place multiple screws into the head fragment and the ability to contour the plate to fit the anatomic configuration of the proximal-lateral humerus. Early screw pullout from the humeral head with loss of reduction has been reported following open reduction and internal fixation with plates and screws (12). However, appropriate patient selection to avoid patients with poor bone quality may decrease this complication.

Extramedullary stabilization with minimal internal fixation offers the potential advantage of less soft-tissue dissection. This theoretically could result in a lower incidence of avascular necrosis. The disadvantage, however, is that fixation may be suboptimal and prevent early motion. These types of extramedullary fixation include pins, screws, tension band or figure-of-eight wires, and combinations of these methods (16).

IV. My Personal Approach

The goal of operative stabilization of any four-part fracture is an anatomic reduction. There is no one correct method to achieve this. Moreover, as one's experience with operative treatment of proximal humerus fractures in general increases, preferred operative techniques may mature or change. This section is meant to be a guide to one person's method of four-part fracture management at one point in time. As the reader encounters patients in his or her own practice with four-part fractures requiring operative stabilization, hopefully these thoughts will provide a backdrop of sound surgical principles that lead to anatomic reduction and stable fixation, even if the exact techniques are not the same.

All four-part fractures are stabilized through an anterior deltopectoral approach. Therefore, anesthesia, patient set-up, and superficial surgical approach are the same for all fracture types. Although the choice of anesthetic is made by the patient after a discussion with the anesthesiologist, combined general anesthesia and interscalene block allows for maximum intraoperative control and post-operative pain management.

After adequate anesthesia has been obtained, the operating table is placed in the semi-recumbent position with the back of the table elevated 30-45 degrees. The entire shoulder girdle must be unsupported off the edge of the operating table to insure that adequate radiographs can be obtained and that the arm can be adducted and extended enough to allow placement of a humeral prosthesis if necessary. This can be accomplished by lateralizing the entire patient on a standard operating table so that the shoulder and arm extend over the edge. Alternatively, special operating tables exist that have panels on either side that can be removed to expose the ipsilateral shoulder girdle. Whichever table is used, a padded retaining post should be attached to the table and rest against the thorax to prevent inadvertent pulling of the patient off the table.

The C-arm and image intensifier are brought into the operating room and positioned appropriately. The C-arm should be positioned at the head of the table, parallel to the lateral edge of the table. This will require that the anesthesiologist and his or her equipment be moved over near the opposite extremity. The ability to obtain an anterior-posterior and axillary view should be verified before the surgical field is prepared and draped.

A skin incision is made parallel to the deltopectoral interval. The length of the incision depends upon the proposed fixation plan. If minimal internal fixation methods are planned, the incision may extend 6-8 cm from slightly superior and medial to the tip of the coracoid toward the deltoid tuberosity. If plate fixation is contemplated, a more extensile incision is required and the incision described above is carried distally, all the way to the deltoid tuberosity. The cephalic vein is separated from the pectoralis major and retracted laterally with the deltoid. In most cases, both the deltoid origin and insertion can be preserved. If a plate or blade-plate is utilized, a small portion of the most anterior fibers of the deltoid insertion may need to be released. The clavipectoral fascia is incised lateral to the conjoined tendon of the coracobrachialis and short head of the biceps; the coracoacromial ligament is preserved. The biceps tendon is identified, deep to the pectoralis major tendon, as a guide to the bicipital groove and tuberosity fragments. At this point, the surgical approach changes, based upon the fracture configuration and contemplated fixation method.

A. Acute valgus-impacted fractures

As the long head of the biceps is followed toward the rotator interval, the surgeon will encounter an osseous defect slightly posterior to the bicipital groove. This defect results from separation of the tuberosities as the head was crushed into valgus and impacted onto the humeral shaft. The periosteal sleeve between the tuberosities and the shaft will be intact; care should be taken not to disrupt it. A small periosteal elevator is placed through this osseous defect and the head is tilted back into its normal anatomic position. A 2.5 mm terminally threaded pin is passed percutaneously through the deltoid to the anterolateral surface of the humeral shaft. The axillary nerve can be visualized on the deep surface of the deltoid so that the pin avoids it. The pin is driven in a retrograde fashion from the anterolateral shaft into the reduced head. The approximate angle of the pin is 45 degrees in the coronal plane and 30 degrees in the sagittal plane. Reduction and pin placement are verified by C-arm in both the anterior-posterior and axillary views. A second percutaneous pin is added, parallel to the first one.

The tuberosities are most often reduced anatomically or nearly anatomically with reduction of the head fragment. They are stabilized by interfragmentary nonabsorbable sutures crossed in the fracture site to prevent over-reduction. Bone graft is usually not required in the acute setting. The pins are cut deep to the skin. Standard skin closure is performed.

B. Subacute valgus-impacted fractures

The humeral head fragment in subacute valgus-impacted four-part fractures has undergone early healing to the humeral shaft. The strength of the union between the humeral head and the shaft is a function of the elapsed time from injury. Moreover, the musculo-periosteal sleeve of tissue containing the tuberosities has begun to scar down into its shortened position and periosteal new bone is beginning to form between this sleeve of tissue and the humeral shaft. All of these factors make reduction and stabilization more difficult than in the acute setting.

After identifying the long head of the biceps and following it proximally, the gap between the displaced tuberosities is identified. This will be more difficult than in the acute setting but with careful dissection the defect can usually be found. Any soft-tissue that has formed within the defect is excised so that the lateral margin of the head and the cancelleous surfaces of the tuberosities can be visualized. A small osteotome is driven carefully between the cancelleous undersurface of the head and the proximal humeral metaphysis. This is done very carefully and only a short distance at a time. The osteotome should not traverse the entire width of the humeral head as it might damage the inferomedial periosteal hinge. As the osteotome is advanced slowly across the humerus, it is gently levered superiorly so that the lateral aspect of the head is tilted back into its normal anatomic position. Provisional fixation can be obtained by placing a percutaneous pin through the deltoid and greater tuberosity into the head.

Depending on the elapsed time from injury, the tuberosities may not reduce anatomically. Should this occur, the periosteal sleeve is mobilized by shelling out some of the periosteal new bone. The tuberosities can then usually be reduced. Interfragmentary sutures are placed but not tied at this point.

In the subacute setting, the defect in the proximal humeral metaphysis left when the head was reduced is substantial. In addition, there is often a tendency for the head to collapse back into valgus. For these reasons, a blade-plate is used to support the head and cancellous allograft is packed between the top of the blade and the undersurface of the lateral portion of the head. The sequence of events is as follows. Cancelleous bone chips are packed under the reduced head through the gap in the tuberosities. The interfragmentary sutures between the tuberosities are tied. A malleable template is used to determine the length and contour of the plate. The guidewire from the blade-plate is placed 2-3 mm posterior to the bicipital groove approximately 3 cm distal to the tip of the greater tuberosity. The length of the blade is determined by measuring the guidewire and an appropriate blade plate is chosen and contoured.

The C-arm is used to verify the reduction and guidewire placement before inserting the blade. The blade is then driven over the guidewire into the humeral metaphysis. Usually the blade enters the humerus at or near the original gap between the tuberosities. Consequently the bone is easily penetrated by the blade. The blade is driven up to the humeral head under C-arm guidance. Care is taken not to drive the blade too firmly into the head as this may result in splitting the head fragment or damage to the inferomedial periosteal hinge. At least three bicortical screws are placed through the plate into the humeral shaft. Additional bone graft is packed into the proximal Humerus between the top of the blade and the head. Heavy nonabsorbable sutures are placed from the subscapularis tendon, infraspinatus tendon, and the top hole in the plate. The provisional fixation pin is removed and a standard skin closure is accomplished.

C. Standard four-part fractures

A systematic approach to reduction and stabilization of standard four-part fractures is recommended. Once the four fracture fragments have been identified, the head is aligned with the shaft and the greater tuberosity is reduced to the head fragment. Provisional fixation is obtained by placing a small k-wire from the greater tuberosity into the head and a second k-wire from the anterior aspect of the shaft (out of the way of the proposed area of placement of the plate) into the head. A cloverleaf plate contoured to the lateral cortex of the proximal humerus and with the superior and anterior leaves of the plate removed is placed on the anterolateral surface of the humerus. The plate is fixed to the distal fragment with one bicortical screw so that the top of the plate is approximately 1-2 cm from the top of the greater tuberosity.

The most superior screw in the plate is then placed. The hole should be drilled through the plate up to the subchondral bone using the C-arm to dictate depth. The hole should not be tapped and a partially threaded cancelleous screw is utilized. This is the most important screw in the proximal fragment and should obtain enough purchase to bring the head and greater tuberosity directly up against the plate. The remaining screws in the proximal fragment are placed in a similar fashion. They should be angled to obtain maximum distance between each screw in the head. The remaining bicortical screws in the distal portion of the plate are placed. There should be a minimum of 3 bicortical screws in the distal fragment. The provisional fixation pins are removed.

The lesser tuberosity is reduced last, as described by Esser. It is held provisionally with a small k-wire. It is most easily stabilized to the greater tuberosity using interfragmentary sutures. Alternatively, a small interfragmentary screw can be used. The provisional fixation pin is removed and the final reduction and hardware position are verified using the C-arm. One fluoroscopic view while rotating the humerus will help exclude joint penetration by any of the screws. A standard skin closure is performed.

V. Pearls and Pitfalls

Open reduction and internal fixation of four-part proximal humerus fractures is infrequently indicated and extremely difficult. In addition, multiple fixation options exist and none has met with universal success. It is important to be prepared to use more than one fixation method. Moreover, if a reasonable reduction cannot be attained with stable enough fixation to allow early passive mobilization, prosthetic replacement may be the best option. Therefore, pearl number one-- be prepared for anything!

The difference between one's visual impression of a fracture reduction and radiographic reality can be immense! Operative management of almost all proximal humerus fractures involves some element of indirect fracture reduction. The fragments are cloaked by the rotator cuff and glenohumeral joint capsule. It is much more desirable to become aware of a malreduction with the patient anesthetized in the operating room than in the recovery room. Hence, pearl number two—use intra-operative radiographs or C-arm frequently.

It is unlikely that every fragment will be reduced anatomically on the first attempt. Even if two fragments are reduced adequately, the reduction may be lost when the remaining fragments are reduced or when additional hardware is placed. Furthermore, whatever reduction has been obtained must be verified radiographically. Pearl number three, therefore, is to use provisional fixation whenever possible.

The final pearl is to remember that the rotator cuff tendons are often stronger fixation points than the bone. Fixation obtained with any metallic fixation device can be reinforced with nonabsorbable sutures incorporating the rotator cuff tendons and the fracture fragments or plate. For example, the most proximal hole in a blade-plate is an excellent anchoring point for heavy nonabsorbable sutures passed through the tendon-bone junction of the rotator cuff.

Percutaneously placed pins can be a source of infection if left outside the skin. Often, pins protruding from the skin will drain. Oral antibiotics are ineffective in treating established pin tract infections. If the pin tract infection is not treated appropriately, chronic osteomyelitis may result. Therefore, if a protruding pin begins to drain, it should be removed. Cutting the pins below the skin can prevent pin tract infections and the potential complication of osteomyelitis.

VI. Post-operative Rehabilitation

In general, post-operative rehabilitation is similar in all types of operatively stabilized four-part fractures described above. Ideally, passive joint mobilization with pendulum exercises, supine passive flexion, and passive external rotation should begin on post-operative day one. However, rehabilitation should be tailored according to the quality of fixation obtained. As a general rule, pendulum exercises begin within the first post-operative week. Radiographs are taken at the time of initial follow-up, which is usually 7-10 days. If there is no displacement of the fracture and no hardware migration, supine passive flexion and external rotation commence. Another radiograph is taken at approximately 4-6 weeks postoperatively. If no problems are encountered, an overhead pulley is instituted. Passive stretching exercises within pain tolerance are instituted at 8-10 weeks post-operatively. Another radiograph is obtained 12 weeks post-operatively. If no radiographic signs of hardware failure or loss of reduction are identified, active, active assisted, and strengthening exercises are added and continue for 3-6 months. Final radiographic follow-up is obtained at 6 months post-operatively.

Percutaneously placed pins will cause irritation of the deltoid during rehabilitative exercises. The patient should be encouraged to perform the exercises within his or her pain tolerance. The pins can be removed at 3-4 weeks post-operatively; this will dramatically improve exercise tolerance. Other hardware such as plates and blade-plates do not require removal. However, if the patient develops symptoms from the hardware such as subacromial impingement, the plate should not be removed for one year post-operatively, unless radiographic union is absolutely certain. If the plate has been in for one year, there are no signs of hardware failure or loosening, the fracture reduction has not changed, and the fracture line(s) are not visible on routine radiography, fracture union is likely and the plate can be removed.

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