CHAPTER 2

Percutaneous Treatment of Proximal Humerus Fractures

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Proximal humerus fractures are common, and about 80% are well managed nonsurgically. The remaining 20% present a therapeutic challenge because surgical stabilization is necessary to ensure healing and to optimize function. The priorities in surgical stabilization of proximal humerus fractures are (1) restoring the anatomic relationship between the tuberosities and the articular head fragment and (2) maintaining vascularity of the articular fragment.[1] Open reduction and internal fixation may allow for rigid fracture fixation, but soft-tissue dissection may endanger residual vascularity of the articular segment. Closed reduction followed by percutaneous fixation reduces risk from soft-tissue dissection and may reduce the fracture indirectly, achieving provisional fixation for anatomic healing. This technique requires meticulous attention to detail and teamwork among the surgeon, surgical assistants, nursing staff, and anesthesia staff.

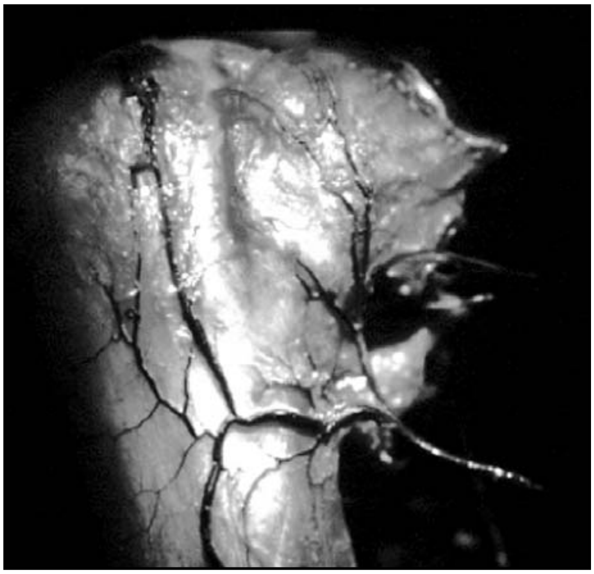
History

Closed reduction and percutaneous fixation was first described by Bohler[2] for the treatment of pediatric proximal humerus fractures. He reduced the fracture with the patient under general anesthesia and provisionally fixed the humeral head fragment to the shaft using percutaneously placed pins. This method then was adapted to the treatment of fractures in adults. Initially, the technique was applied to the management of two-part surgical neck fractures[3] where it was as successful as open methods. More recently, closed reduction and percutaneous fixation with pins and cannulated screws has been applied to the management of three- and even four-part proximal humerus fractures.[4-6] Although these approaches to more complex fractures are challenging, vascularity of the humeral head seems to be more reliably preserved than in open treatments that require soft-tissue dissection to place rigid fixation implants.[7] The incidence of osteonecrosis is reduced with these methods[4-6,8-12] because the prinicipal vascular supply to the humeral head, the ascending branch of the anterior circumflex humeral artery, is left undisturbed with no dissection in the region of the bicipital groove or around the subscapularis (Figure 1). Indeed, this method has been termed “bio-logical” fixation.[1] The learning curve clearly is steeper for three- and four-part fractures than for two-part surgical neck fractures.

Indications

The specific indications for closed reduction and percutaneous pinning include proximal humerus fractures without significant comminution in patients with good quality bone who are willing to comply with the postoperative care plan, which includes serial radiographs

FIGURE 1



Articular vascularization of the humeral head. *(Reproduced with permission from Gerber C, Schneeberger AG, Vinh TS: The arterial vascularization of the humeral head: An anatomical study.* J Bone Joint Surg Am *1990;72:1486-1494.)*

and shoulder immobilization for 4 to 6 weeks. Certain fracture patterns are easier to manage than others, and these are outlined briefly below.

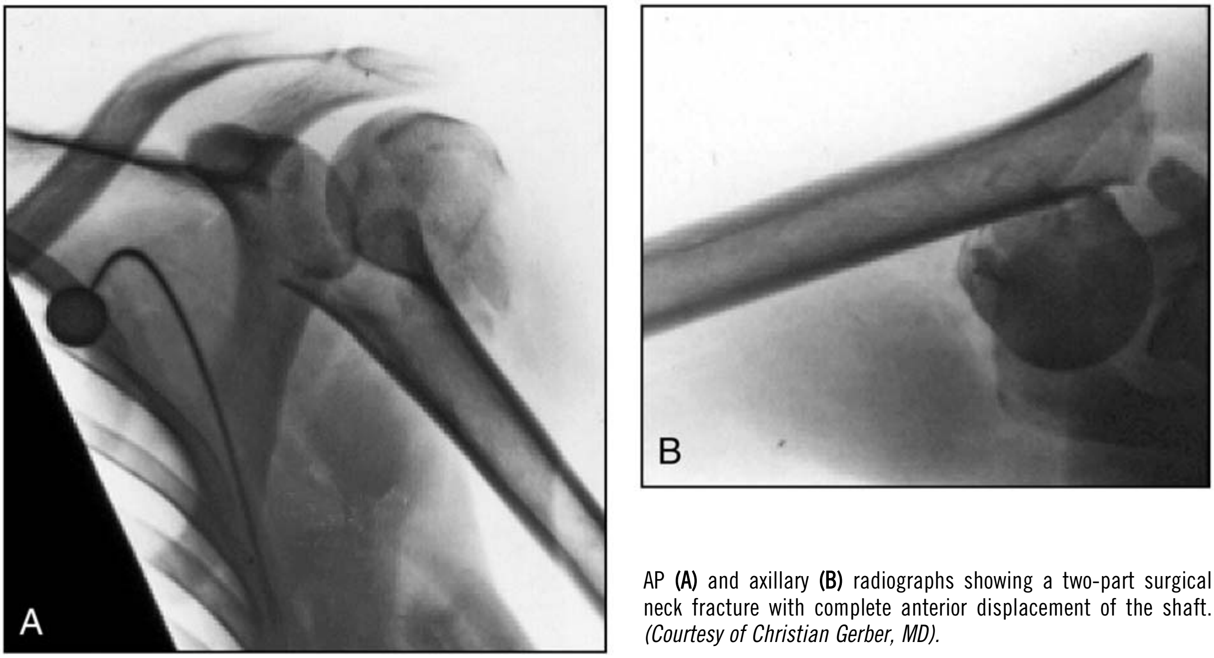
Two-Part Surgical Neck Fractures: The Shallow Learning Curve

The ideal indication for closed reduction and percutaneous pinning is a two-part surgical neck fracture in which there is marked displacement and/or angulation that will not achieve acceptable healing and restore function (Figure 2). Most patients with these fractures are younger and have good quality bone that permits secure fixation once reduction is accomplished. Patient compliance with postoperative care also is very important.

Three-Part Valgus-Impacted Fractures: The Steeper Learning Curve

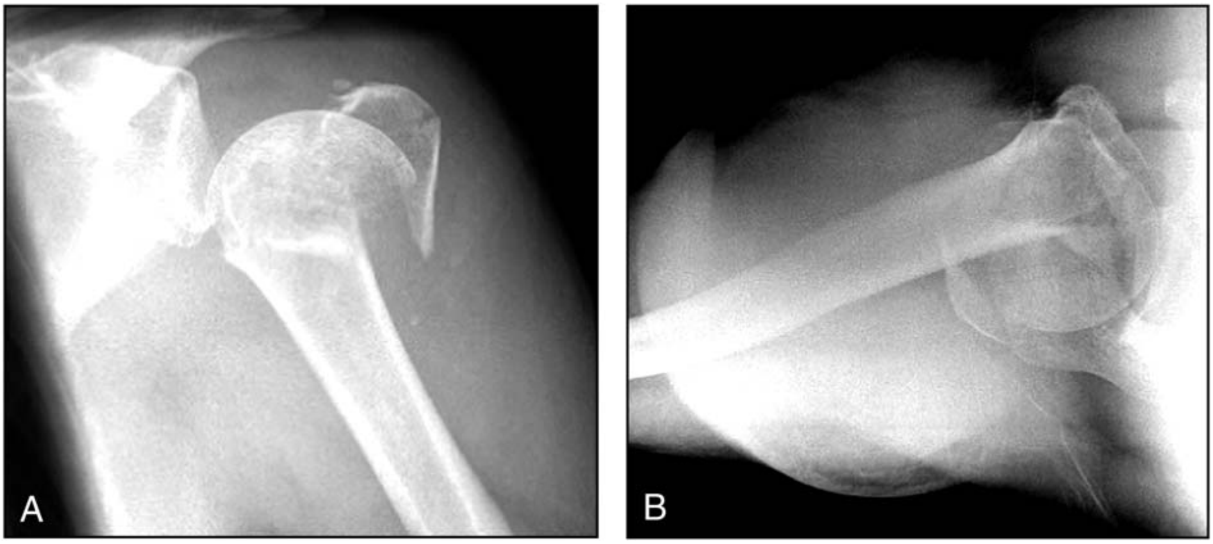
This distinct fracture pattern recently has been recognized as being amenable to closed reduction and percutaneous fixation. It is more difficult to treat than the two-part fracture pattern because it requires manipulation of the articular segment into its proper position followed by stable fixation of the tuberosity to the head and to the shaft (Figure 3).

FIGURE 2



AP **(A)** and axillary **(B)** radiographs showing a two-part surgical neck fracture with complete anterior displacement of the shaft. *(Courtesy of Christian Gerber, MD).*

FIGURE 3



AP **(A)** and axillary **(B)** radiographs of a three-part valgus-impacted fracture.

Four-Part Fractures: The Steepest Learning Curve

Four-part fracture configurations are challenging because adequate reduction and fixation require manipulation of tuberosity fragments into position with percutaneous hooks and pins, followed by stable fixation using combinations of pins and screws (Figure 4).

CONTRAINDICATIONS

Severe comminution and osteopenia are absolute contraindications to closed reduction and percutaneous fixation (Figure 5). Inability to reduce fracture fragments is another reason to abandon this approach and convert to open reduction. Fracture-dislocations also may be impossible to manage using a closed technique. Finally, patients who will not be compliant with postoperative immobilization and the need for pin removal are not good candidates for this method of treatment.

SURGICAL TECHNIQUE

The first and perhaps most important step in achieving a good outcome is proper patient selection. This decision-making step is essential, and guidelines have been outlined in the previous sections. The next key steps are technical and include careful planning and preparation so that all of the appropriate equipment and the necessary team are available. The proper operating room setup is essential, and nursing and anesthesia staff should be aware of the specific positioning needs. The fluoroscopic C-arm operator should rehearse the steps needed to obtain proper, repeatable, biplanar radiographs before the patient's arm is prepared and draped so that the C-arm can be positioned easily and without error during the procedure. Finally, an assistant should be present who understands how to achieve and maintain the reduction and then allow for fixation.

Access to the fractured shoulder is paramount. Specific instrument requirements include a beach chair that allows for complete access to the shoulder for fluoroscopic imaging or a long beanbag that can be contoured to support the patient and allow access to the shoulder. A mechanical arm holder can also help significantly. Reduction instruments should include bone elevators and hooks to manipulate fragments. The necessary implants are 2.5-mm terminally threaded pins (terminal threads reduce chance of migration out of bone) and 4.0-mm cannulated screws. Finally, a drill with a quick-release for the pins and the appropriate chuck attachment for the cannulated screws should be available.

FIGURE 4

Four-part fracture *(Courtesy of Evan Flatow, MD)*

FIGURE 5

Severe metaphyseal-diaphyseal comminution in a patient with an anterior dislocation. This fracture is not amenable to closed reduction and percutaneous fixation. *(Courtesy of Christian Gerber, MD)*

Positioning

The patient is positioned on a special beach chair or on a regular operating room table with a long beanbag contoured medial to the scapula to ensure that the entire shoulder girdle is freely exposed for fluoroscopic imaging (Figure 6). A fluoroscopic C-arm is then oriented parallel to the table so that it comes either over or under the shoulder from a position at the head of the table (Figure 7). It may be necessary, depending on the size of the room, to angle the table and move it downward in the room to make space for the C-arm. The image receiver is positioned on the opposite side of the table toward the foot so that the surgeon can see it easily while performing the reduction and fixation. The C-arm is then rotated into an AP view and an axillary view to ensure these views can be obtained easily once the patient's shoulder is prepared and draped.

Closed Reduction

The patient's muscles must be completely relaxed so that the surgeon can manipulate the fracture fragments to obtain reduction. This condition is obtained either with general anesthesia and muscle relaxants or with a successful regional interscalene block.

In the case of a two-part surgical neck fracture, or a three-part fracture in which there is significant displacement of the shaft from under the humeral head, a trial reduction is performed to confirm the feasibility of closed reduction and percutaneous fixation before sterile preparation and draping of the patient's arm. If the shaft cannot be reduced under the humeral head, the fracture pattern may be unstable or there is interposed soft tissue, and open reduction is indicated.

In many patients, the humeral shaft is either angulated with the apex anterior or completely displaced anteriorly as a result of the pull of the pectoralis major tendon. Reduction is performed by applying longitudinal traction with the arm in minimal abduction and some flexion (Figure 8). This position will relax tension on the pectoralis major, and posterior pressure on the humeral shaft may then reduce both displacement and angulation between the shaft and the humeral head fragments.

FIGURE 6

A, Positioning of a patient on a special beach chair (T-Max, Tenet Medical Engineering, Calgary, Canada) that allows full exposure of the shoulder for fluoroscopy. **B,** Positioning of a patient on a long beanbag contoured medial to the scapula so that the entire shoulder girdle is freely exposed for fluoroscopic biplanar imaging.

When closed reduction is confirmed, the shoulder and arm are sterilely prepared and an articulated arm holder is used to support and position the arm during the procedure (Figure 7). This arm holder permits reproducible, consistent positioning of the arm and allows the assistant to help with the fixation of the fracture.

Percutaneous Fixation With Pins

Two-Part Surgical Neck Fracture

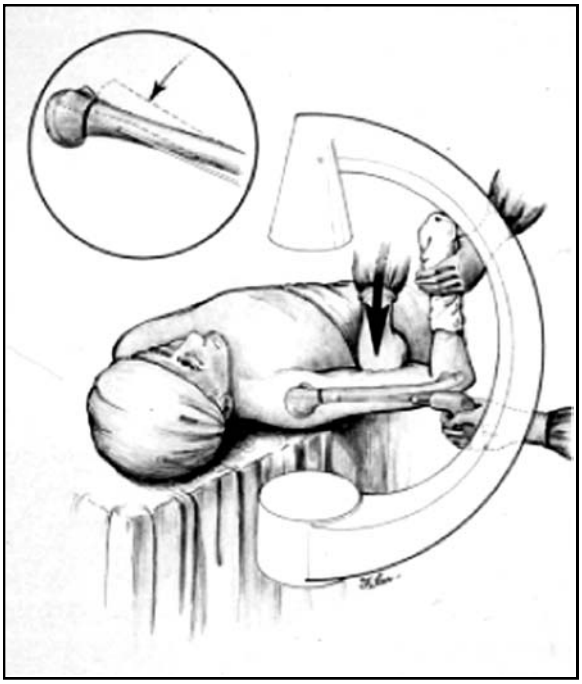
In a two-part surgical neck fracture, the reduction maneuver is repeated as described, then the shaft is fixed to the articular segment as follows (Figure 9): A 2.5-mm terminally threaded pin is held over the shoulder, and a fluoroscopic AP image is obtained. The pin is positioned over the humeral head, coming from the lateral humeral shaft up into the head. The angle of the pin is marked with a skin marker on the shoulder. A small incision is then made over the lateral arm at the level determined by the fluoroscopic image, and a straight clamp is used to spread the soft-tissue down to the humeral shaft. The tip of the clamp can confirm the anterior and posterior cortex of the humerus. The 2.5-mm terminally threaded pin is then positioned at this location through the small stab incision and confirmed with a fluoroscopic image. It is helpful to insert the pin into the lateral humeral cortex at a more horizontal angle so that the pin will not initially skate off the lateral cortex, which makes the angle more vertical. While the assistant maintains the reduction, the surgeon drills the pin up into the humeral head, confirming pin position with either spot radio-graphs or fluoroscopic control until the pin tip is just beneath the articular surface. Because the humeral shaft is in 20° of retrotorsion, the pin should be aligned in this orientation as it is inserted. The drill then is removed from the pin, and the shoulder is rotated while fluoroscopic imaging confirms that the pin is in the proper position. An axillary view should be obtained; however, simply rotating the shoulder into internal and external rotation will give a relatively quick and accurate assessment of pin placement.

A second pin is drilled parallel to the first pin so that

FIGURE 7

Positioning of a patient with the fluoroscope in position. The C-arm is draped with a sterile material and positioned at the head of the operating table. The arm is supported with a sterile, articulated arm holder (Spyder, Tenet Medical Engineering, Calgary, Canada).

FIGURE 8



Closed reduction maneuver accomplished with distraction, flexion, and abduction. *(Reproduced with permission from Jaberg H, Warner JJ, Jakob RP: Percutaneous stabilization of unstable fractures of the humerus.* J Bone Joint Surg Am *1992;74:508-515.)*

the two pins are spread apart (ideally, 1.5 to 2.0 cm) in the humeral head. Finally, a third pin is placed through a small stab incision located anterior to the first incision so that this pin will enter the humeral head from an anterior direction. If necessary, a fourth pin can be added from an anterior direction for additional stability.

In some patients, an antegrade pin that enters from the greater tuberosity into the humeral shaft may be necessary. However, we have found this rarely to be the case in two-part surgical neck fractures.

Avoiding Pitfalls

The danger zones for pinning are the axillary nerve, which passes approximately 5 cm distal to the lateral edge of the acromion from posterior to anterior, and the radial nerve, which passes around the spiral groove of the humerus. The orientation of the lateral pins almost always is below the axillary nerve and above the radial nerve; however, we always spread the soft tissue down to bone with a small clamp before placing the pin into the incision.

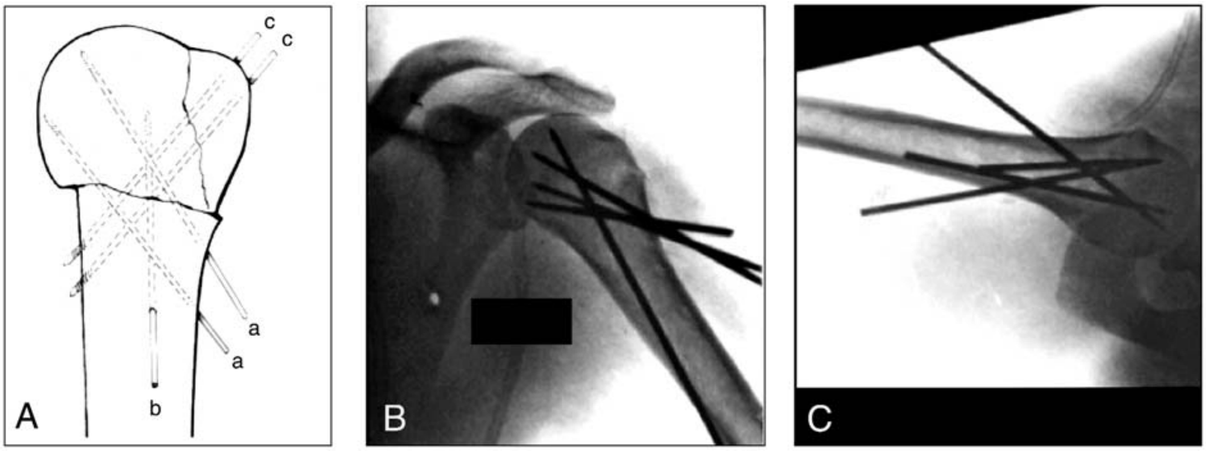
Anteriorly, the long head of the biceps tendon is a relative surgical danger, and medially, the anterior circumflex humeral vessels along the medial cortex also are considered a relative danger area.

It is imperative to obtain biplanar images during the procedure to assess pin placement in the humeral head, thereby avoiding penetration into the joint.

Three-Part Valgus-Impacted Fracture

In a three-part valgus-impacted fracture, the humeral articular fragment is tilted down into valgus, and the greater tuberosity remains at the correct height. The surgeon can use an indirect reduction maneuver, which takes advantage of soft-tissue tension in the rotator cuff and periosteum, to reduce the articular and greater tuberosity segments. Once the shaft has been positioned under the articular segment as described, a small inci-

FIGURE 9



A, Percutaneous pin fixation technique. *(Reproduced with permission from Jaberg H, Warner JJ, Jakob RP: Percutaneous stabilization of unstable fractures of the humerus.* J Bone Joint Surg Am *1992;74:508-515.)* AP **(B)** and axillary **(C)** radiographs showing closed reduction and percutaneous pinning, demonstrating the retrograde technique with 2.5-mm terminally threaded pins. *(Courtesy of Christian Gerber, MD).*

sion is made laterally at a point that will allow an elevator to be placed into the fracture under the humeral head. The humeral head is then levered upward out of valgus and into proper varus alignment. This maneuver can be done under fluoroscopic control and should be very gentle so as not to risk fracturing the humeral articular segment. As the humeral head is tilted up out of valgus, the rotator cuff and periosteum will pull the greater tuberosity under the humeral articular segment, and in some patients, this will be an obvious reduction. While the surgeon holds this reduction in place, the assistant makes a small lateral incision above the first incision and places either 2.5-mm terminally threaded pins from the greater tuberosity or guidewires from the 4.0-mm cannulated screw set into the humeral head (Figure 10). The cannulated drill can be placed over the guide wires so that 4.0-mm screws of proper length can be used to fix the greater tuberosity to the articular segment, avoiding placement of pins through the rotator cuff and proximal deltoid. Several cannulated screws or pins should be used to fix the greater tuberosity to the humeral shaft in an antegrade orientation.

Four-Part Fracture

It occasionally may be possible to fix a four-part fracture in young patients with good quality bone using these techniques. The reduction and fixation of the humeral shaft and the greater tuberosity to the articular segment are performed as described. In patients in whom the greater tuberosity remains superiorly or posteriorly displaced, a 2.5-mm pin can be used as a joystick to manipulate the fragment into place so that it can be fixed to the humeral segment. Small hooks also can be used to accomplish the reduction (Figure 11).

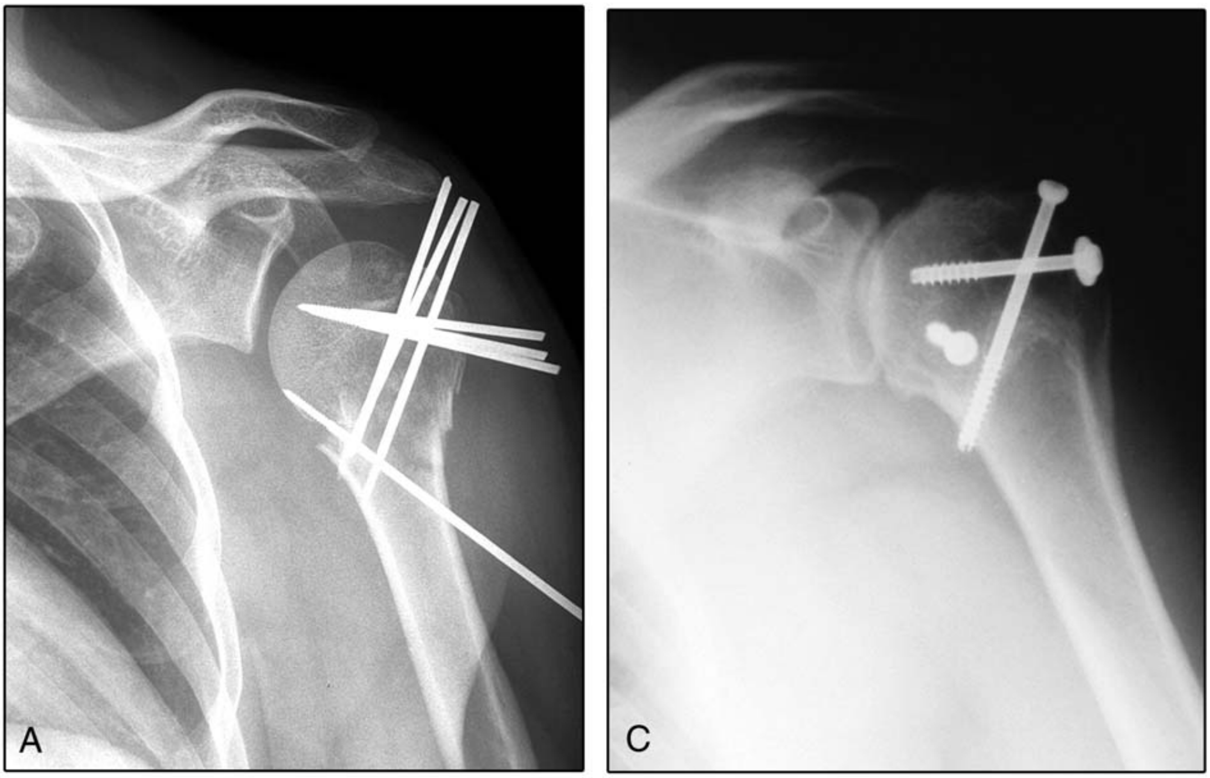
The lesser tuberosity fragment also may require reduction, which is performed by internally rotating the arm and using a small hook placed through a small lateral incision to pull this fragment into position over the anterior humeral shaft. It is then fixed with 4.0-mm cannulated screws.

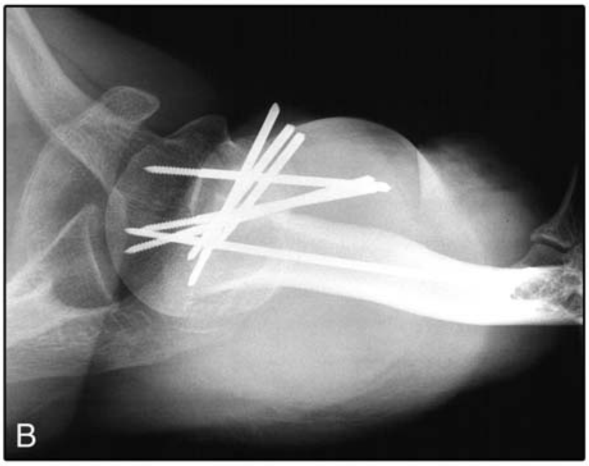
In all patients, final biplanar images should confirm reduction in both the AP and axillary planes. Some degree of malreduction of the shaft to the humeral head segment is acceptable as long as the configuration is stable; however, the tuberosities must be reduced into an anatomic position to avoid loss of motion resulting from malunion and mechanical blockage.

Aftercare

The pins are trimmed so that they are below the skin, which is closed with monofilament suture. The pins may become prominent as the swelling from the original injury subsides; therefore, the pins should be monitored to ensure that skin penetration is not imminent. If a pin penetrates the skin, it can be trimmed on an outpatient basis. The patient remains in the hospital overnight, and

FIGURE 10





Postoperative AP **(A)** and axillary **(B)** radiographs of a three-part valgus-impacted fracture demonstrating anatomic reduction and fixation with 2.5-mm terminally threaded pins. **C,** Postoperative AP radiograph 2 years after closed reduction and percutaneous fixation of a four-part fracture with cannulated screws. Notice anatomic fracture union and no evidence of osteonecrosis. *(Courtesy of Evan Flatow, MD)*

prophylactic parenteral antibiotics are administered for the first 24 hours postoperatively.

The shoulder is placed into an immobilizer, and no motion is permitted for 4 weeks. However, if fixation has been achieved using cannulated screws so that no pins are placed from an antegrade proximal position adjacent to the acromion, pendulum exercises are permitted in the first week after surgery.

A plan is made to return to the ambulatory operating room 4 to 6 weeks after the initial surgery to remove the

FIGURE 11

A, Valgus-impacted fracture. **B,** Mechanism of percutaneous reduction using a bone tamp to elevate the humeral head and a pin to joystick the greater tuberosity into place. **C,** Pinning after closed reduction.

provisional pin fixation. The patient is evaluated in the physician's office each week to check the pins, and biplanar images are obtained to ensure that pin migration has not occurred and that fracture reduction is maintained.

When the pins are removed, the patient begins active-assisted motion in a supervised physical therapy program. An aquatherapy program in which the patient is instructed to stretch the shoulder actively in a gravity-free buoyant environment of warm water also assists recovery of motion. Ideally, the patient should see a

FIGURE 12

Final clinical result after closed reduction and percutaneous fixation of a three-part valgus-impacted fracture.

physical therapist three times each week for the first 4 to 6 weeks after surgery and attend aquatherapy at least twice a week after the pins are removed and the incision has healed. Using this approach, residual motion loss is rarely problematic.

Radiographs are obtained at 2 or 3 months after surgery, at which time complete radiographic union usually is apparent. Strengthening of the shoulder usually is begun at about 3 months after surgery.

RESULTS

The results of closed reduction and percutaneous pinning are favorable in most series.[3-6,8-11] The largest two series have been published by Jaberg and associates[3] and Resch and associates.[4,6]

Jaberg and associates[3] treated 54 unstable proximal humerus fractures with follow-up of 2 to 7 years (mean, 3 years). Of the 48 patients available for follow-up, 34 had a good or excellent result, 10 had a fair result, and 4 a poor result (loss of fixation). Osteonecrosis developed in two patients, and partial osteonecrosis developed in eight. This series was the first that inspired enthusiasm for this technique.

In 1997, Resch and associates[4] reported their experience treating the more complex patterns of three- and four-part fractures with closed reduction and percutaneous pinning. In this series, 27 patients were treated: 9 had three-part fractures, and 18 had four-part fractures, 13 of which were valgus impacted. Average follow-up was 2 years. The Constant score for three-part fractures was 91%, and no patients had osteonecrosis. For four-part fractures, the Constant score was 87%; however, 11% had osteonecrosis, and two patients required revision to a prosthesis for persistent pain.

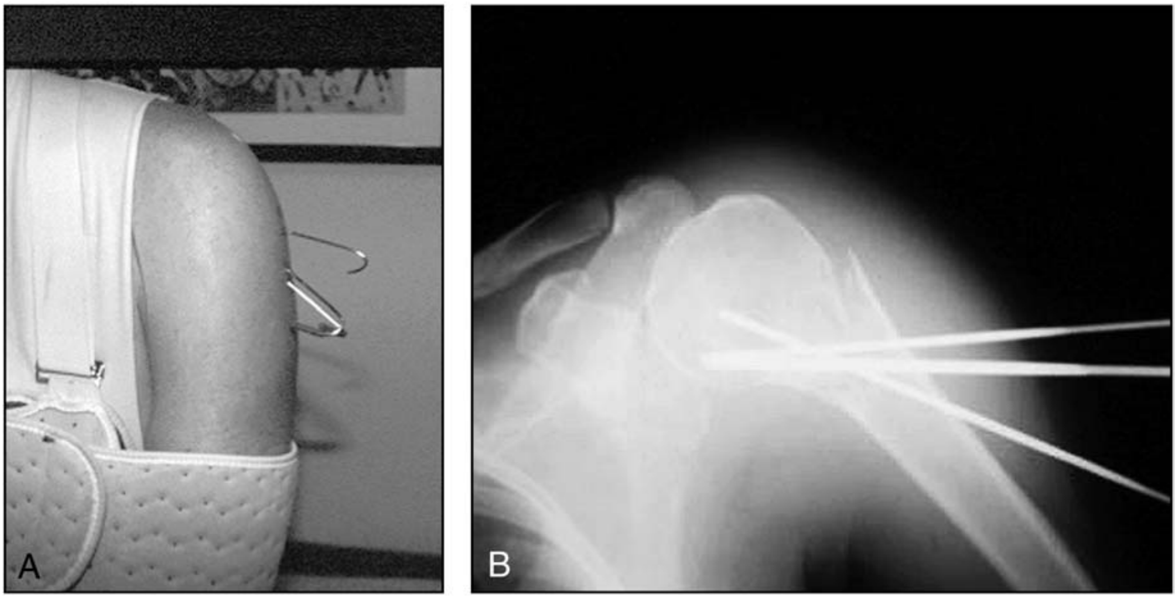
In a follow-up study, Resch and associates[6] performed closed reduction and percutaneous fixation on 88 patients. The initial 27 patients (9 with type B1 and B2 fractures and 18 with type C1 and C2 fractures) were reported in follow-up. The type B1 and B2 fractures had a Constant score of 91%, indicating good to very good functional results; the type C1 and C2 fractures had a Constant score of 87% and an osteonecrosis rate of 11%. The authors concluded that the soft-tissue bridging of the various fragments was crucial for the reduction to benefit from the ligamentotaxis effect, and that this technique worked well for valgus-impacted or three-part fractures. The rate of osteonecrosis was low, and rehabilitation was easier because of limited adhesions within the surrounding tissues. Overall, the results from these series are quite encouraging.

Over the past 5 years, we have performed closed reduction and percutaneous fixation of 16 proximal humerus fractures. All patients have regained overhead motion and have achieved stable fixation (Figure 12). No osteonecrosis was observed; however, none of our patients had true four-part fractures.

PITFALLS AND FAILURES

Common pitfalls usually result from surgeon error and include inappropriate patient selection, inadequate reduction, convergence of pins, use of too few pins, or use of smooth pins with loss of reduction (Figure 13).

FIGURE 13



Technical errors associated with pin placement. **A,** Too few pins that were smooth and were left outside the skin. A pin tract infection developed in this patient. **B,** The pins were not widely displaced in the humeral head but instead were placed in a converging pattern into the articular segment. This led to a fracture nonunion.

Other causes include loss of reduction caused by failure to recognize comminution at the fracture site and pin tract infection caused by leaving pins outside the skin after the procedure.[13,14]

Conclusion

Closed reduction and percutaneous fixation is a useful technique in select patients with unstable proximal humerus fractures. Although the technique is demanding, the results are predictably good if meticulous attention is paid to the reduction and fixation steps. Furthermore, the biologic rationale of minimizing soft-tissue dissection to preserve articular vascularity is a very sound reason to select this approach in some three- and four-part fractures. The surgeon should develop skill and confidence with the technique with two-part fractures and then move to the more difficult three- and four-part fractures as his or her skills improve. The keys to success are proper setup, a careful reduction to restore the anatomy, a biomechanically sound pin configuration to maximize fixation, appropriate aftercare to achieve healing, and avoidance of complications.

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