Severely Impacted Valgus Proximal Humeral Fractures

Surgical Technique

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INTRODUCTION

Impacted valgus fractures are an important subgroup of complex proximal humeral fractures that have a good prognosis for healing because of the intact medial capsular blood supply to the humeral head. Less severe forms of these fractures can be successfully treated nonoperatively or with use of minimally invasive internal fixation techniques. However, when severe impaction of the humeral head and displacement of the tuberosities occur, restoration of adequate shoulder function depends on successful reduction and stabilization of these structures.

Although adequate reduction of the key fracture fragments can be achieved with use of minimally invasive techniques, it has been our experience that maintaining reduction is often difficult with percutaneous internal fixation techniques. Secondary displacement of both the humeral head and the tuberosities often occurs, perhaps because of instability caused by the cancellous bone defect behind the reduced humeral head and by the inadequacy of screw fixation alone. We developed a new open operative technique in an attempt to address these problems. A stable fracture configuration following reduction of the humeral head is achieved by filling the resultant defect with bone substitute, and subsequent internal fixation is augmented by interosseous suture repair of the tuberosities.

SURGICAL TECHNIQUE

We believe that the procedure ideally should be performed within the first week after the injury, although it is often feasible to reduce the fracture fragments as late as two weeks after the injury; we recently performed the surgery at this later stage for patients in whom the diagnosis had been delayed. After the induction of general anesthesia, the patient is positioned supine in the beach-chair position, continued
FIGS. 1-A THROUGH 1-D Clinical photograph (Fig. 1-A), diagram (Fig. 1-B), and radiographs (Figs. 1-C and 1-D). In all figures, the right shoulder is shown from the side, with the patient in the beach-chair position. The upper and right margins of each figure are superior and anterior, respectively. **Fig. 1-A** Patient positioning for surgery in the beach-chair position, with the image-intensifier on the opposite side of the shoulder table. **Fig. 1-B** Rotation of the C-arm allows both anteroposterior and “modified axial” views to be made intraoperatively.
with a shoulder operating table “cut-away” to facilitate access for the image-intensifier from the opposite side of the table. It is important to ensure secure fixation of all anaesthetic tubing, which should be cleared from the path of the image-

into ≥160° of valgus and the greater tuberosity was displaced by >1 cm. All patients were treated with open reduction of the fracture, and the space created behind the humeral head was filled with Norian Skeletal Repair System (SRS) bone substitute. The fractures were stabilized with either screws or buttress plate fixation. Associated rotator cuff tears were repaired. All patients underwent functional outcome assessment with use of the Constant, DASH (Disabilities of the Arm, Shoulder and Hand), and SF-36 (Short Form-36) scores at one year, and twelve patients were followed for two years.

RESULTS:
All fractures united within the first year, all reductions were maintained, and no patient had signs of osteonecrosis of the humeral head on the latest follow-up radiographs. At one year, the median Constant score was 80 points and the median DASH score was 22 points. The functional results continued to be satisfactory in the twelve patients who were followed for two years. The results in our series were better than those achieved in studies of nonoperative treatment of similar fracture configurations. There were six clinically relevant complications, although none required a reoperation and all six patients had a satisfactory short-term functional outcome.

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intensifier to prevent inadvertent detachment during surgery. By rotating the image-intensifier, both anteroposterior and “modified” axial views can be obtained during surgery to assess the fracture reduction, to monitor the insertion of bone substitute, and to visualize the position of the internal fixation (Figs. 1-A through 1-D). Routine antibiotic and antithrombotic prophylaxis is used for all patients. The whole arm is prepared and draped in order to allow free movement of the arm by the assistant during surgery.

We use a deltoid-splitting approach through a shoulder-strap skin incision because it provides better access to the humeral head and tuberosities than does a standard deltopectoral approach (Figs. 2-A and 2-B). The modified skin incision is more cosmetically acceptable than the standard longitudinal deltoid-splitting approach and is especi-
FIG. 3
Clinical photograph showing the distally-based skin flap that is used to facilitate the subsequent deltoid-splitting approach.

FIG. 4
Clinical photograph showing the split deltoid, the axillary nerve (blue sling), and the long head of the biceps (yellow sling).

FIG. 5
Clinical photograph showing the axillary nerve (blue sling), which usually lies in close proximity to the depressed humeral head and the fractured tuberosities. It is routinely identified and protected throughout surgery. GT = greater tuberosity, LT = lesser tuberosity, and HH = humeral head.
INDICATIONS:
Patients with a severely impacted valgus fracture of the proximal part of the humerus who are medically fit for anesthesia, who are less than eighty-five years old, who are mentally alert and oriented (with a mini-mental test score\(^4\) of >8 of 10), and who have a history of normal shoulder function prior to the injury should be considered for surgery.

We believe that patients who have an impacted fracture in which the inclination angle (the angle between the intramedullary axis and the perpendicular to the articular surface margin) has been tilted into ≥160° of valgus are suitable candidates for treatment with this technique. Most of these patients also have substantially displaced tuberosity fractures.

CONTRAINDICATIONS:
Medically frail, demented, and uncooperative patients and patients who are more than eighty-five years old are treated nonoperatively in our unit, irrespective of the apparent severity of their impacted valgus fracture as seen on radiographs. Relative contraindications to surgery include rheumatoid arthritis, prolonged type-I diabetes, immunocompromise, a history of heavy smoking or alcoholism, and the presence of severe risk factors for osteoporosis.

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Clinical photograph (Fig. 6-A) and diagram (Fig. 6-B) showing the impacted humeral head in the rent between the two tuberosities, both of which have been tagged with multiple stay sutures. GT = greater tuberosity, LT = lesser tuberosity, and HH = humeral head.
We believe that most fractures in which the inclination angle has been tilted to <160° are best treated nonoperatively, although we consider surgery for younger individuals (those who are sixty years old or less) if the tuberosities are substantially displaced. The technique is inappropriate when there is massive impaction (creating a volume of >20 mL to be filled) behind the humeral head after it has been reduced. In these circumstances, we use either a structural allograft (for uncontained defects) or morselized allograft (for contained defects) to fill the large void behind the humeral head. We believe that this technique is also inappropriate for fractures in which the humeral head is either separated from the tuberosities and shaft or dislocated from the glenoid cavity. Although we now treat many of these fracture patterns with a humeral head-conserving procedure, the massive comminution that is usually encountered means that the use of bone substitute is not feasible and allograft is used instead.

Critical Concepts

Elliptical flap is developed (Fig. 3) to allow the deltoid to be split longitudinally over a substantial length (Fig. 4). The axillary nerve is in close proximity to the fractured tuberosities and the displaced humeral head, and it is routinely identified and protected throughout the procedure (Fig. 5). The path of the nerve as it runs transversely across the deltoid split creates two soft-
tissue windows. The window above the nerve allows access to the humeral head and tuberosities for reduction and stabilization, and the window below the nerve allows access to the proximal part of the humeral shaft and creates a safe area for screw insertion if plate fixation is required. A standard anterior acromioplasty is performed for all patients to reduce the risk of later rotator cuff impingement.

After retraction of the deltoid, the split in the tuberosities is identified to allow access to the humeral head. This split usually is readily apparent because the humeral head is typically facing superiorly or superolaterally with the tuberosities splayed on either side of it (Figs. 6-A and 6-B). In most patients, both tuberosities are fractured and substantially displaced, although the displace-
The component of the greater tuberosity is often more readily apparent because of its larger size. A substantial rent in the rotator cuff, propagating through the rotator interval, also is not uncommon and, if present, is repaired later with nonabsorbable sutures. Next, three or four nonabsorbable interosseous sutures are inserted through each tuberosity to facilitate handling. The humeral head is elevated and reduced with a blunt dissector under image-intensifier control (Figs. 7-A and 7-B). The humeral shaft tends to displace medially below the humeral head, and we have found that the insertion of a custom-made bolster into the axilla at this point helps to lateralize and reduce the humeral shaft under the humeral head at the site of the fracture and also helps to avoid excessive handling in this potentially unsterile area (Fig. 8). Once the head is adequately reduced, it is temporarily secured with threaded Kirschner wires that are inserted through the proximal part of the humeral shaft and into the head.

The metaphyseal cavity that is created behind the humeral head after it has been reduced is irrigated to clear away blood and debris, and then the cavity is filled with Norian Skeletal Repair System (SRS) bone substitute (Norian, Cupertino, California). As with ordinary bone cement, the material is injected in a semiliquid form, although the curing time is slower (fifteen minutes). A specially designed cement gun with a narrow cannula...
is used to deliver the cement to the deepest recesses of the cavity, after which it is gradually withdrawn to fill the more superficial areas in a retrograde fashion. Careful monitoring with an image-intensifier is required throughout the injection process to ensure that there is no extravasation of cement into the soft tissues. The greater and lesser tuberosities are then sutured together by tying the interosseous stay sutures to create a closed cavity behind the humeral head to contain the SRS during setting (Fig. 9). We believe that these interosseous sutures are critical to the stability of the reconstruction and help to prevent early tuberosity pull-off.

The fracture reduction is then stabilized by internal fixation with positional screws, without any attempt being made to compress the osteoporotic metaphyseal bone. In patients who have a single greater tuberosity fragment, stabilization can be achieved by fixing the greater tuberosity to the humeral head and/or proximal humeral metaphysis with use of two, three, or four 3.5-mm partially threaded cannulated screws. In patients who have substantial comminution of the greater tuberosity (more than two separate fragments), secure fixation with screws alone is not possible, and a contoured cloverleaf buttress plate is used to maintain the reduction (Figs. 10-A and 10-B).

CRITICAL CONCEPTS | continued

AUTHOR UPDATE:
In general, we believe that many of these more complex fractures of the proximal part of the humerus, which would have been deemed to be unreconstructable and treated with hemiarthroplasty ten years ago, can now be treated with a humeral head-conserving procedure as a result of the new technologies that are now available. Since the time of publication of our original article and as our experience has grown, we have introduced modifications to the technique.

As described above, we now routinely identify and protect the axillary nerve throughout the procedure. The greater safety that this maneuver affords during insertion of internal fixation devices has resulted in a trend toward the use of plate fixation rather than more minimal individual screw fixation to stabilize the reconstruction. We now use plate fixation in the majority of our patients because we believe that it imparts greater mechanical stability to the reconstruction.

As our confidence in the stability of our reconstructions has grown, we have reduced the period of postoperative immobilization from six to four weeks.

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Care must be taken to avoid any tension on the axillary nerve as the plate is inserted underneath it. Similarly, the nerve must be carefully protected during insertion of the two or three cortical screws into the lower end of the plate, through the lower soft-tissue “window.”

All hardware should be placed as low as possible in the tuberosities in order to minimize the risk of later impingement. If a plate is used, it is important to ensure that it is positioned correctly below the apex of the greater tuberosity (as seen on the image-intensifier) in order to reduce the risk of later impingement. The anterior leaf of the plate should be placed just posterior to the bicipital groove. It is also essential to ensure that none of the screws are inadvertently placed within the joint. Several safeguards are available to avoid this problem. First, the drill is inserted at low speed and can be felt to encounter resistance when it comes into contact with the hard subchondral bone of the humeral head. Second, the depth gauge is advanced similarly until the hard subchondral bone is felt. Third, screw length is a compromise between avoiding the joint penetration that results from the use of a screw that is too long and the poor fixation that results from the use of a

**CRITICAL CONCEPTS | continued**

Younger patients (those who are less than sixty years old) may commence active-assisted range-of-motion exercises immediately postoperatively. Initially, we rested all shoulders in internal rotation (the so-called safe position) postoperatively. We now place the shoulder in a position of neutral rotation, neutral flexion, and neutral abduction, with the elbow flexed to 90°, with use of a custom-made splint (Fig. 12). We believe that this facilitates the early recovery of shoulder movement once the sling has been removed.

**FIG. 11-A**

Postoperative anteroposterior (Fig. 11-A) and modified axial (Fig. 11-B) radiographs.
A screw that is too short; however, most screws that are inserted into the head should be between 40 and 50 mm in length, if placed properly. Fourth, once all screws have been inserted, careful final screening should be carried out with use of the image-intensifier, with the shoulder positioned in full internal and external rotation on both the anteroposterior view and the modified axial view (Figs. 11-A and 11-B).

After copious lavage of the wound with saline solution, a meticulous suture repair of the deltoid is required, especially at the top end of the incision, where the deltoid is detached from the acromion. Early redetachment of the deltoid is a potentially disastrous complication of this approach. We use multiple interrupted nonabsorbable sutures for the lower end of the repair, and we use multiple transosseous sutures to repair the upper end of the deltoid to the acromion. A layered closure of the subcutaneous tissues and skin is then performed.

In all patients, the shoulder is immobilized in a sling for four to six weeks after the operation. Pendulum exercises and elbow range-of-motion exercises are commenced immediately, with active-assisted range-of-motion exercises beginning at two weeks after the operation. Abduction of the shoulder beyond 90° or external rotation beyond the neutral position are prohibited during this period. Isometric rotator cuff exercises and gradu-
ated active range-of-motion exercises, performed under the supervision of a physiotherapist and supplemented with a home-exercise program, are commenced after removal of the sling and then are continued for at least six months after the operation.

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REFERENCES


