The subacromial bursa is excised and the key

However, operative treatment of Fractures and nonunions in which there is a varus

We routinely also obtain preoperative fine-

2 The

varus deformity is severe. We describe a simple technique to assist in the open reduction and locking plate stabilization of this challenging and complex fracture subtype using tools and implants that are readily available in most modern orthopaedic trauma operating rooms.

Key Words: technical trick, varus fractures, reduction, internal fixation

(J Orthop Trauma 2011;25:634–640)

INTRODUCTION

Proximal humeral fractures with severe varus deformity (head-shaft angulation less than 100°) of the humeral head when treated nonoperatively may be associated with poor functional outcomes and increased risk of nonunion.1 The humeral head usually retains a vascular supply after this type of fracture, and early open reduction and locking plate fixation is increasingly recommended to improve the functional outcome and reduce the risk of subsequent nonunion or symptomatic malunion.2 However, operative treatment of these fractures poses unique problems during reconstruction and is associated with a higher rate of acute fixation failure.3–9 These practical problems include the difficulty in reducing the humeral head from its posteroinferiorly subluxated position and maintaining reduction while performing definitive plate fixation. It is important to adequately reduce the varus deformity and obtain stable internal fixation, because early failure is associated with inadequate humeral head reduction or defective placement of screws within the humeral head.3–9 We describe a technique that facilitates these key steps during reconstruction of both acute fractures and nonunions in which there is a substantial varus deformity of the humeral head. The technique is simple and uses equipment that is readily available in a general orthopaedic trauma department.

Surgical Technique

We routinely obtain a trauma series of conventional radiographs comprising both an anteroposterior scapular plane radiograph (directly tangential to the glenoid face with the forearm positioned in neutral rotation and the shoulder in zero degrees of flexion and abduction) and a modified axial or Velpeau view.10 We routinely also obtain preoperative fine-slice spiral computed tomograms with three-dimensional reconstruction to assist in preoperative planning. This helps to estimate the triplanar displacement of the head with respect to the shaft and facilitates preoperative planning of the reduction. For three- and four-part intra-articular varus fractures, this investigation also helps to recognize the presence and extent of any radiologically occult marginal head-splitting fracture that may be attached to one or both tuberosities. However, we do not consider this investigation to be essential to performing the described technique.

The patient is positioned in the beachchair position using either a shoulder attachment to the standard operating table or a fully adjustable modular table with a shoulder cutout. Standard antibiotic and antithrombotic measures are used. The skin is prepared and draped to allow free access of the fluoroscope from the opposite side of the operating table. An extended deltoid-splitting approach is performed through either a straight lateral or shoulder-strap incision.11–13 The straight lateral incision is used if the fracture extends beyond the metaphysis distally, and the shoulder strap incision is used if the fracture is confined to or above the metaphyseal area.11,12 The area in which the anterior branch of the axillary nerve traverses the deltoid is carefully identified and protected with a vessel loop sling throughout the procedure. This creates two “windows” to the proximal humerus through the deltoid split, one above and one below the area where the nerve traverses the deltoid. The upper window is used for manipulation of the head and any tuberosity fragments, and the lower window is used for placement of the lower plate screws into the proximal diaphysis.11,12 The subacromial bursa is excised and the key fracture fragments are identified. The reduction of the varus

Accepted for publication November 12, 2010.

From The Shoulder Injury Clinic, Edinburgh Orthopedic Trauma Unit, The New Royal Infirmary of Edinburgh, Edinburgh, UK.

No funds were received in support of this work.

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

The authors declare no conflicts of interest.

Reprints: C. Michael Robinson, BMed, FRCSEd (Orth), Consultant Orthopaedic Surgeon, The New Royal Infirmary of Edinburgh, Old Dalkeith Road, Edinburgh, EH16 4SU, UK (e-mail: c.mike.robinson@ed.ac.uk).

Copyright © 2011 by Lippincott Williams & Wilkins

634 | www.jorthotrauma.com

J Orthop Trauma • Volume 25, Number 10, October 2011

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.
deformity is performed slightly differently dependent on whether the fracture configuration is entirely extra-articular (Neer two-part surgical neck fracture) or an intra-articular Neer three- or four-part fracture with or without head split. The technique used also varies slightly dependent on whether the fracture is acute or a nonunion.

**Acute Extra-Articular Neer Two-Part Surgical Neck Fracture**

The proximal humeral diaphysis is typically displaced either directly laterally or anterolaterally with respect to the humeral head in varus fractures (Fig. 1). A provisional reduction of this displacement is performed initially under direct vision. From preoperative templating we determine the appropriate length of Philos plate (Synthes, Welwyn Garden City, UK), which will allow adequate fixation distal to the site of the fracture. If proximal diaphyseal bone has a cortical thickness of more than 4 mm, we choose a plate length that will allow six cortices of fixation distal to the fracture (three bicortical screws). If the proximal humeral diaphyseal cortical thickness is 4 mm or less, or if there is extensive metaphyseal comminution, we select a plate that will allow eight cortices of fixation distal to the fracture site (four bicortical screws). From preoperative planning, the extent of varus angulation of the humeral head is measured, and this gives an accurate assessment of the degree of correction that is required to recreate an optimal head-shaft inclination angle of 130°.

Under fluoroscopic control, an unthreaded stout 2-mm or 2.7-mm Kirschner wire is used to place a provisional starting hole in the lateral cortex of greater tuberosity, 1 cm below the apex of the tuberosity on the anteroposterior fluoroscopic view and 1 cm posterior to the bicipital groove. A Philos plate of appropriate length is then positioned against the provisionally reduced proximal humeral diaphysis and is purposely positioned such that the Kirschner wire can be placed back into the pilot hole through the most anterosuperior screw hole in the plate at an angle of approximately 90° to the lateral cortex of the unreduced humeral head (Fig. 2). The superior aspect of the plate should be positioned lateral to and above the apex of the greater tuberosity at this point. Maintaining this angulation with respect to the lateral cortex, the wire is now advanced to the subchondral bone beneath the humeral head articular surface (Fig. 3). Using fluoroscopic views, it is important to ensure that the wire lies in the equatorial position of the humeral head or just above it on the anteroposterior view and directly in the equatorial position of the head on the modified axial or Velpeau view (Fig. 3).

A second 2.7-mm wire is now inserted parallel to the primary wire through the posterosuperior plate hole. The protruding ends of the wires are now moved distally to “joystick” the humeral head from its varus posteroinferiorly subluxated position into an anatomic position (Fig. 4) such that the head-shaft inclination angle is restored to 130°. This can be confirmed by direct measurement under fluoroscopic control. Restoration of the normal “Gothic” arch of the shoulder also confirms the adequacy of the reduction. The plate is moved distally as a result of the reduction maneuver such that it assumes a position below the apex of the greater tuberosity (Fig. 5).

It is important to ensure simultaneously that there is adequate correction of any lateral plane translation, impaction or angulation, and any rotational deformity at this stage. We recognize two subtypes of shaft displacement from the head associated with varus fractures. In the first type there is minimal translation, but the shaft is impacted superiorly within the head. Correction of all components of the deformity is usually relatively easy for this fracture subtype. In the second type, there is anterior translation and angulation of the shaft in relation to the humeral head, usually with complete dissociation of the two parts. There is complete disruption

---

**FIGURE 1.** Preoperative anteroposterior (A) and Velpeau lateral (B) radiographs of an extra-articular two-part varus fracture in a 73-year-old woman.
of the soft tissue sleeve, which links the head to the shaft and correction of lateral plane and rotation deformity is usually more challenging. The use of the two plate–joystick Kirschner wires facilitates correction of lateral plane and rotational displacement, but if there is persistent deformity, supplementary independent joystick Kirschner wires or reduction clamps may be used. If the reduction is very unstable, as a result of extensive posteromedial calcar comminution, the wire can be temporarily advanced across the joint space to transfix the reduced humeral head to the glenoid. It is important not to move the humeral head in the presence of this temporary transfixation wire, because the wire may fracture at the level of the joint. Temporary transfixation enables supplementary bone grafting procedures aimed at restoring posteromedial stability²−¹⁷ to be performed while the reduction is maintained anatomically.

FIGURE 2. Intraoperative view of the right shoulder showing the two windows produced by the extended deltidoid-splitting approach either side of the axillary nerve, which is protected within the blue sling. The Kirschner wire is eccentrically positioned through the anterosuperior hole of the Philos plate, which is purposely superior and lateral to the unreduced humeral head.

FIGURE 3. Intraoperative fluoroscopic view showing the Kirschner wire advanced through the plate into the subchondral bone in the middle of the humeral head.

FIGURE 4. Intraoperative view of the reduction maneuver to “joystick” the two Kirschner wires distally to reduce the humeral head from its varus position. Note how this advances the plate distally and into the wound such that it lies against the lateral cortex of the reduced proximal shaft.

FIGURE 5. Intraoperative fluoroscopic view, showing the reduction of the humeral head from its varus position. The Philos plate is advanced distally such that it lies against the lateral cortex of the reduced head and proximal shaft.
It is important to check at this point that the plate is also positioned just below the lateral eminence of the greater tuberosity to prevent later problems related to plate impingement against the acromion. If the plate is malpositioned, it can be corrected at this stage by removing the implants, altering the Kirschner wire starting point, replacing the plate, and repeating the reduction maneuver.

Definitive plate fixation is now performed while the reduction is maintained either by transfixation or by maintaining the orientation of the Kirschner wire joysticks (Fig. 5). The plate is first secured to the reduced head by inserting one or two locking screws of appropriate length into the head. The plate is then definitively reduced and fixed to the shaft using one of the lower plate shaft screws. If the reduction is not anatomic, the plate may lie slightly lateral to the shaft before this step; fixation of the shaft to the plate using a conventional nonlocking screw has the effect of further increasing the valgus angulation of the head and this may be used to “fine-tune” the reduction at this point. The reconstruction is then completed by inserting the remaining plate and shaft screws. A jig that attaches to the proximal end of the Philos plate greatly assists in the placement of the monoaxial locking screws within the head so that the threads in the screw heads engage properly in the plate. The jig increases the overall bulk of the implant as it is slid against the shaft. It is important to ensure that undue tension is not placed on the anterior branch of the axillary nerve during this maneuver (Fig. 2). We use between seven and nine locking humeral head screws. The joystick Kirschner wires are then withdrawn and replaced with head locking screws. We consider it essential to use fill the two locking screws holes in the lowest of the four rows of head screws in the plate. This is because these screws are directed along the lowest aspect of the humeral head in the region of the calcar. Unlike the other screws in the head, they are therefore under compression rather than tension and therefore act to “buttress” the area of bony instability the area of the posteroinferior calcar. The shaft screws are inserted according to the preoperative templating (Fig. 6). Our personal preference is to use nonlocking screws in the diaphysis. The positive tactile feedback achieved during screw tightening confirms that good bicortical purchase has been obtained. If there is severe osteoporosis (cortical thickness less than 4 mm), locking screws may be required in the diaphysis.

Intra-Articular Neer Three- and Four-Part Fractures

For these fractures, it is important to ascertain whether there is a portion of the humeral head articular surface attached to any displaced greater or lesser tuberosity fragment (Fig. 7). The articular fragment attached to the tuberosity may not be immediately apparent at the time of surgery, because the periosteal sleeve between the tuberosity fragment and the humeral head is usually intact, preventing a direct view of the articular surface. Preoperative computed tomograms with three-dimensional reconstructions greatly assist in the evaluation of the integrity of the humeral head articular surface before surgery (Fig. 7C). The primary goal of reconstruction is to reduce and stabilize any displaced articular split and then to ensure that there is secure fixation of any displaced tuberosity fragment to the humeral head. The articular reconstruction is best achieved under direct vision by developing the tuberosity fracture line to form an arthrotomy to visualize the humeral head articular surface. If the fracture line is close to the rotator interval, it is best if the arthrotomy is performed in this area to avoid further damage to the rotator cuff. The articular split is most easily reduced and stabilized using a cannulated screw system, either a traditional 3.5-mm or conical headless...

FIGURE 6. Anteroposterior (A) and Velpeau lateral (B) radiographs of the final reconstruction. Note the two inferior calcar screws that provide a buttress effect for the area of potential instability in the area of the posteromedial calcar.
Acutrak (Acumed, Andover, UK) screws (Fig. 8). If the bone quality is poor or there is extensive comminution of the tuberosity fragments, the reconstruction may be supplemented by an interosseous or transtendinous suturing technique using a modern ultrastrong braided suture such as Orthocord (Ethicon, Edinburgh, UK). The sutures may be tied to each other independently or though the marginal Kirschner wire holes in the plate. The use of the latter technique may create a tension band effect to offload the screw tip–bone interface. Once the tuberosity fragments are secured to the humeral head, the reconstruction of the head to the proximal diaphysis can proceed as for an extra-articular two-part fracture (Fig. 9). Care should be taken when positioning the joystick Kirschner wires to avoid placing them through fracture lines, which may redisplace reduced and fixed tuberosity fragments.

Nonunions

Head-shaft nonunions after nonoperative treatment are commonly associated with severe varus deformity. If the fracture was originally an intra-articular three- or four-part fracture, the tuberosities are usually malunited to the head fragment and we do not attempt to correct this at surgery. The head-shaft nonunion is often synovial and this is excised together with all surrounding fibrous membrane and scar tissue. The bone ends of the proximal shaft and the humeral head are identified and burred back until two bleeding surfaces are produced. If there is no significant bone loss or erosion of the humeral head (usually in nonunions of less than 1 year’s duration), the reconstruction can then proceed as for an extra-articular two-part fracture. More commonly, there is extensive erosion and bone loss in the humeral head and restoration of the normal anatomy is not possible without leaving a substantial metaphyseal bone gap. In these circumstances, we prefer to appose the freshened bone to create “bayonet” reduction of the proximal diaphysis within the humeral head once it is reduced using the plate–joystick technique. This frequently produces inferior subluxation of the humeral head in the early postoperative period as a result of the shortening, which is performed at the time of the surgery causing rotator cuff inhibition. This gradually corrects within the first 6 weeks after the surgery.

Irrespective of the fracture type, we rest the arm in a shoulder immobilizer and, other than simple pendulum exercises, is rested for 4 weeks after surgery. Pendular exercises and elbow range-of-movement exercises are performed during this time. Isometric exercises of the rotator cuff and graduated range-of-movement exercises are started after sling removal.

Clinical Experience

Between July 2008 and August 2009, the senior author used this technique in the treatment of 16 varus fractures (10 females, six males; mean age, 63.9 years; range, 39–83 years) with varus proximal humeral fractures. Using the Neer classification, nine were two-part surgical neck fractures, four were three-part lesser or greater tuberosity fractures, and three were four-part fractures. There was an articular split requiring supplementary screw fixation in four cases. The pre- and postoperative translational deformity, shortening, and angulation of the head to the shaft at the fracture site on the anteroposterior and modified axial radiographs were routinely measured using the techniques described by Boileau et al. These are summarized in Table 1. The reduction has been
maintained in all cases in which the technique has been used on radiographs taken within the first year after injury. There have been no early fixation failures or revisions surgeries in these patients.

DISCUSSION

Proximal humeral fractures with a varus deformity of the humeral head are increasingly recognized as a common and important subgroup of proximal humeral fractures. The extent of the varus deformity is not easily assessed using conventional radiographic views. Many fractures that previously would have been classified as simple Neer two-part fractures are now recognized to have significant varus deformity of the humeral head when assessed using computed tomography with three-dimensional reconstruction. When the humeral head deformity is severe, these injuries may be associated with a poor functional outcome after nonoperative treatment owing either to malunion of the head causing rotator cuff dysfunction and stiffness or as a result of the development of a nonunion. However, the humeral head is usually viable after this type of injury and the risk of osteonecrosis of the humeral head is relatively low. These fractures are therefore well suited to operative treatment by open reduction and internal fixation, rather than replacement arthroplasty, which may be frequently associated with disappointing functional outcomes.

The innovations in surgical approaches to the proximal humerus, together with the advances in plate technology and bone substitutes, have reduced the threshold for operative treatment of proximal humeral fractures and nonunions in the last 10 years. The locking plate is the most widely used implant to treat these injuries by internal fixation and has the advantage over other techniques such as percutaneous fixation and intramedullary nailing that the plate can be used as a tool to achieve provisional fracture reduction. Nevertheless, these fractures are prone to fixation failure as a result of instability at the posteromedial calcar of the humeral head, which predisposes to failure through secondary redisplacement of the humeral head back into its position of varus angulation. The importance of achieving accurate reduction of the humeral head and avoiding persistence of varus deformity have therefore been highlighted.

In addition, a locking plate functions as a lateral tension band such that all superior screws in the humeral head are under tension, except the lower screws inserted into the region of the calcar. Placement of these calcar screws is thought to be important together with the use of adjuvant techniques to restore stability if there is excessive posteromedial calcar comminution with techniques such as fibular or allograft femoral head buttress grafting being advocated.

We feel that the technique that we have described provides a relatively simple method of reliably achieving a satisfactory reduction of the varus deformity of the humeral head using the plate together with supplementary Kirschner wires as a “tool” to reduce the fracture. The technique allows adjuvant bone grafting techniques to be used to stabilize the posteromedial calcar while maintaining the fracture reduction. The plate may then be used to fine-tune the reduction and achieve definitive stabilization of the fracture. If the reduction technique is followed correctly, the plate is usually positioned such that the two lowest calcar-buttressing screws can be inserted to reduce the risk of fixation failure.

Before the development of this technique, we used Kirschner wires or osteotomes to initially reduce the fracture and then attempted to apply the locking plate separately while attempting to maintain the reduction. This was frequently problematic because the wires or osteotomes tended to obstruct the area in which the plate was to be placed, frequently leading to plate malposition or loss of reduction. The use of the combined

**FIGURE 9.** Anteroposterior (A) and Velpeau lateral (B) views of the final reconstruction of the patient shown in Figure 8. The plate has been advanced distally by the joystick reduction, the Kirschner wires have been removed once the head, and shaft screws are all in place.
plate and Kirschner wires has therefore greatly simplified this technique when using the extended lateral deltoit-splitting approach. The deltopectoral approach is still the most widely used surgical approach to treat proximal humeral fractures. The difficulty in placing Kirschner wires accurately in the humeral head using this approach may dictate that our described technique is less effective. An alternative technique using the deltopectoral approach is to link the Philos plate to the unreduced humeral head using locking screws such that the plate lies at an angle to the diaphysis. Reduction of the plate to the diaphysis then reduces the varus deformity of the head. This technique is not applicable to the extended deltoid splitting approach, because the eccentric initial lateral positioning of the plate places undue tension in the area of the deltoid split at which the anterior branch of the axillary nerve is situated, increasing the risk of nerve injury during fracture manipulation. However, we feel that our described technique of achieving reduction first is more reliable in this alternative technique, even when performed through a deltopectoral approach. This is because the reduction is confirmed and fine-tuned before plate fixation is performed, and therefore there is more control of the reduction before definitive fixation is achieved.

Our technique has the advantage of simplicity, does not require specialist instrumentation or implants, and can be readily using in most orthopaedic shoulder trauma specialists who are familiar with the use of existing locking plate technology. We feel that the technique greatly simplifies the reduction and subsequent internal fixation of this complex and challenging subgroup of proximal humeral fractures.

REFERENCES


TABLE 1. Change in the Radiologically Visible Proximal Humeral Angulation and Displacement After Operative Treatment Using the Joystick Technique

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean Preoperative Measurement (range in parentheses)</th>
<th>Mean Postoperative Measurement (range in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varus angulation on anteroposterior radiograph</td>
<td>72° (20°–85°)</td>
<td>132° (128°–134°)</td>
</tr>
<tr>
<td>Head-shaft translation on anteroposterior radiograph</td>
<td>1.9 cm (0.6–3.8 cm)</td>
<td>0.2 cm (0–0.3 cm)</td>
</tr>
<tr>
<td>Shortening on anteroposterior radiograph</td>
<td>2.6 cm (1.4–3.8 cm)</td>
<td>0.1 cm (0–0.4 cm)</td>
</tr>
<tr>
<td>Head-shaft angulation on modified axial radiograph</td>
<td>43° (5°–56°)</td>
<td>4° (0°–12°)</td>
</tr>
<tr>
<td>Head-shaft translation on modified axial radiograph</td>
<td>2.5 cm (0.2–4.3 cm)</td>
<td>0.2 cm (0–0.5 cm)</td>
</tr>
<tr>
<td>Shortening on modified axial radiograph</td>
<td>3.8 cm (2.4–4.8 cm)</td>
<td>0.2 cm (0–0.4 cm)</td>
</tr>
</tbody>
</table>