the AP external rotation fluoroscopic view (Figure 7), the shaft of the humerus should be under the humeral head, the greater tuberosity should be approximately 5 to 10 mm below the top of the head, and the articular surface should point toward the upper portion of the glenoid (RH Cofield, MD, Rochester MN, personal communication, 1998). Additional precision can be gained by referencing the image of the opposite shoulder. A reasonable attempt should be made to match the tuberosity height and neck-shaft angle of the opposite shoulder. Additional fluoroscopic views are used as necessary to assess translation and angulation of the humeral shaft relative to the head, the position of the lesser tuberosity, and the position of the head segment relative to the glenoid. The course of the long head of the biceps tendon is checked to confirm the rotational accuracy of the reduction. The provisional reduction should be scrutinized, and final adjustments should be made before the hardware is placed. The most common pitfall is the persistent varus position of the head segment. In most instances, this problem is easily resolved by slightly backing out the provisional Steinmann pin and adding additional provisional

Figure 4  A, AP radiograph showing a valgus-impacted four-part fracture. B, Intraoperative fluoroscopic image showing elevation of the humeral head using a square-tipped impactor placed through a coronal split in the greater tuberosity.

Figure 5  Schematic drawings showing a modification of the valgus impaction osteotomy. A, The transverse line delineates the intended level of the osteotomy. Prominent edges of the shaft anteriorly and laterally are trimmed with a rongeur to create a relatively flat surface that will allow balanced compression of the head segment. B, The “trimmings” are placed into the head segment and function as local bone graft. C, The head segment is supported by upward impaction of the shaft. The position of the head segment is adjusted with traction sutures placed at the bone-tendon junction of the subscapularis and supraspinatus tendons. (Reproduced with permission from the Mayo Foundation of Medical Education and Research, Rochester, MN.)
and fracture-dislocations. Subtraction views show bony Bankart lesions and articular fractures of the humeral head that may be difficult to detect on some two-dimensional images. For a three- or four-part fracture, three-dimensional CT also reveals what, if any, part of the greater or lesser tuberosity is attached to the head segment. Any area of continuity between the tuberosities and head segment may serve as a “handle” to indirectly reduce the head segment with traction sutures placed at the bone-tendon junction of the rotator cuff (the so-called string puppet reduction technique). The use of three-dimensional CT has made it possible to plan the surgical exposure, reduction maneuvers, and hardware positioning and to anticipate the need for bone grafting (Figure 2).

**Surgical Technique**

**Operating Room Setup for Fluoroscopic Imaging**

The optimal operating room setup allows unrestricted access to the shoulder for fluoroscopic imaging. Most surgeons prefer using a standard operating table and some variation of the familiar beach chair patient position. The table is turned 90° after induction of anesthesia, so that the injured shoulder is opposite the anesthesia team and the equipment. This position allows the C-arm to enter and exit the field from the head of the operating table. Regardless of the setup and patient positioning, it is wise to verify that a minimum of two high-quality fluoroscopic views can be obtained prior to draping (Figure 3). This step is critical for the prevention of intraoperative screw penetration.

**Exposure**

The extended deltopectoral approach is preferred because of the options for extensile exposure to address almost any proximal humeral fracture pattern, including fracture-dislocations. The interval from the clavicle to the deltoid insertion is developed, while preserving the muscle origin and releasing a portion of the insertion as needed. The sub deltoid space is mobilized with care to avoid the terminal branches of the axillary nerve. A Brown deltoid retractor is placed. Abduction of the arm relaxes the deltoid and allows access to the entire greater tuberosity and rotator cuff.17 During the exposure and placement of hardware, every attempt is made to respect the primary blood supply to the humeral head by avoiding the anterior circumflex vessels as they course along the subscapularis and the arcuate artery as it courses along the bicipital groove.

**Extensile Maneuvers**

Fractures of the proximal humerus occasionally extend into the diaphysis. For this pattern, the exposure is carried distally (the Henry approach), and a long plate is applied to the lateral aspect of the humerus. In this situation, the deltoid insertion is released, but doing so does not appear to have any clinical se-
quelae, in the absence of a brachial plexopathy. Conversely, dissection can be extended proximally and medially to enter the glenohumeral joint so that a humeral head articular fracture or glenoid rim fracture can be treated. In patients with neurovascular injury, the brachial plexus and axillary artery can be explored through the deltopectoral interval.

**Reduction Maneuvers**

Reduction maneuvers are determined by the fracture pattern. Impacted fractures are elevated using the method described by Jakob and associates (Figure 4). Unimpacted fractures are compressed using the “parachute technique” described by Banco and associates (Figure 5). A valgus impaction osteotomy allows balanced compression of the head segment on the shaft. This technique relies on tension band sutures and is ideally suited for reducing two-part surgical neck fractures. The method also can be used to reduce three-part fractures if the anterior portion of the greater tuberosity is connected to the head segment.

Although the principles of the parachute technique can be applied to most proximal humeral fractures, contraindications do exist. The reduction method is dependent on an intact rotator cuff and cannot be used in fractures in which the tuberosities are detached from the head segment, impacted fracture patterns, and fractures with severe metaphyseal comminution. In fractures with metaphyseal comminution, the parachute technique can result in excessive humeral shortening and inferior instability. In these cases, humeral length can be restored with bone grafting. Options for bone graft material include autograft, allograft, or a synthetic substitute. Restoration of humeral length is also important in treating complex anterior fracture-dislocations in which the proximal humerus and glenoid are fractured (Figure 2). If humeral length is not restored, it can be difficult to keep the humeral head concentrically reduced in the postoperative period. This situation is particularly problematic in patients with an associated axillary nerve injury.

**Humeral Head Support**

The concept of humeral head support has been emphasized by several authors. Most often, the head segment is supported by the shaft of the humerus. If there is moderate or severe traumatic bone loss, bone graft or a bone graft substitute is used. A soft humeral head supported only by rigid hardware tends to settle onto the metal. The result is
active assisted range-of-motion exercises are initiated. Radiographs taken 12 weeks after surgery usually show fracture consolidation (Figure 12). At this point, use of the sling is discontinued, and the patient is encouraged to use the arm for light daily activities, including driving and shopping. More forceful activities, such as yard work, tennis, and golf, are avoided for 6 months.

Results

General

There are few studies in the literature on the topic of proximal humeral fracture fixation in elderly patients. Hintermann and associates reported on 42 patients older than 50 years with three- and four-part humeral fractures who were treated with internal fixation with a blade plate. Although fracture healing was reliable, 11 secondary procedures were needed mainly to treat postoperative stiffness and prominent hardware. The authors advocated primary open reduction of all three- and four-part humeral fractures regardless of the patient’s age.

Banco and associates reviewed outcomes of a valgus impaction osteotomy for treating two-part fractures. Thirteen patients with a mean age of 68 years were treated with the
possible, unless significant swelling has already developed. One deep and one subcutaneous drain are placed; the type of approach used will dictate the method of closure. The skin should be closed with staples or interrupted sutures.

**Dealing With Metaphyseal Bone Loss**

Adequate bony contact with interfragmentary compression in the supracondylar region is necessary to ensure the stability of the construct and eventual fracture union at this level. If metaphyseal bone loss or comminution precludes an anatomic reconstruction with satisfactory bony contact, the humerus can be shortened at the metaphyseal fracture site, provided that the overall alignment and geometry of the distal humerus are restored. This alternative reconstructive technique is called supracondylar shortening (Figure 7). This technique is especially useful in fractures with combined soft-tissue and bone loss. Shortening by 1 cm or less has only a slight effect on triceps strength in terminal extension. With severe soft-tissue and bone loss, up to 2 cm of humeral shortening can be tolerated without serious disturbance of elbow biomechanics (Figure 8). If necessary, the posterior aspect of the distal humerus can be sculpted with a burr to re-create an olecranon fossa.

**Distal Screw Placement**

When medial-lateral parallel plating is done, screws should not be placed into the distal fragments before the plate is applied. An independent screw does not contribute to supracondylar stability and does not achieve as much stability as it would if it had passed through a plate. It also interferes with the passage of

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**Figure 5** Step 4: supracondylar compression. A, Using a large tenaculum to provide interfragmentary compression across the fracture at the supracondylar level, the lateral column is fixed first. A screw is placed in dynamic compression mode (inset) in hole No. 4 of the lateral plate. Tightening the screw further enhances interfragmentary compression at the supracondylar level (converging arrows) to the point of causing some distraction at the medial supracondylar ridge (diverging arrows). B, The medial column is then compressed in a similar manner, using the large tenaculum and a screw inserted in the medial plate in dynamic compression mode (inset). If the plates are slightly undercontoured, they can be compressed against the metaphysis with a large bone clamp, providing further supracondylar compression. (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN.)

**Figure 6** Step 5: final fixation. All of the smooth Steinmann pins are removed, and the remainder of the screws are inserted. The distal screws interdigitate for maximal fixation in the distal articular fragments. (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN.)
Another pitfall is the inappropriate placement of Kirschner wires for provisional fixation. These wires should be placed in the subchondral region rather than in the center of the articular segments where the screws will go and also need to be placed in a position where they will not interfere with the plates. Anticipating where the plates will be positioned on the bone before placing the temporary Kirschner wires avoids this problem. Placement of the distal articular screws through the plates and across to the other side without violating the joint or the olecranon fossa can be difficult. This is best achieved by using a targeted drill guide and by waiting to replace the 2- or 2.5-mm Steinmann pins in the distal articular segments through each plate with screws until after at least one screw is placed through a second hole of each plate. These pins ensure a pathway for screws to go through the plate into the distal articular segment.

**Figure 7** A supracondylar shortening osteotomy is a viable option when an anatomic reconstruction is not possible or structural bone grafting is undesirable, particularly when associated with severe soft-tissue injuries. **A**, The distal end of the humeral shaft (dark lines; never the articular segments) is reshaped to enhance contact between the distal articular segment and the shaft. **B** and **C**, The limb is shortened through the fracture site to permit interfragmentary compression between the trochlea and the distal shaft, between the capitellum and the distal shaft, and side-to-side on one or both sides. After these surfaces have been compressed and fixed with the plates, there is adequate stability to permit immediate motion and rehabilitation. It is acceptable to translate the distal segment medially or laterally, and also slightly anteriorly, provided that rotational and valgus alignment is maintained. Preoperative (**D** and **E**) and postoperative (**F** and **G**) radiographs of a severe distal humeral fracture with substantial bone loss that was treated with shortening osteotomy. **H** and **I**, Elbow range of motion at most recent follow-up was 0 to 150°. (Reproduced with permission from Mayo Foundation for Medical Education and Research, Rochester, MN.)
the arm abducted and externally rotated, the patient reported pain in the posterior and superior aspect of the shoulder and a relocation test decreased the pain. Recently, Meister and associates\textsuperscript{68} found that a test to elicit pain in the posterior and superior aspect of the shoulder in athletes who threw overhead had a sensitivity of 75.5\% and a specificity of 85\% for identifying rotator cuff and posterior labral tears. Morgan and associates\textsuperscript{62} found that the results of the relocation test varied depending on the type of SLAP lesion (Table 5).

Other tests for the detection of SLAP lesions have been described. However, studies of these tests have varied substantially with regard to their methodology and the types of patient groups in which they were used\textsuperscript{69} (Table 6). One of the most commonly used tests is the active compression test described by O’Brien and associates.\textsuperscript{70} This test has been shown to be highly accurate for diagnosing abnormalities of the acromioclavicular joint.\textsuperscript{71} However, its clinical usefulness for diagnosing SLAP lesions has not been demonstrated in studies with a control group or in those of larger cohorts of patients (Table 7).

In conclusion, the diagnosis and treatment of pain in patients who participate in overhead sports continue to be sources of controversy. Although internal impingement of the rotator cuff on the superior aspect of the glenoid may cause the pain, Morgan and associates\textsuperscript{62} found that patients who had a repair of a SLAP lesion and no associated rotator cuff disease all had an excellent result; conversely, the only patients with a repair of a SLAP lesion who had a poor result were those who had coexisting rotator cuff disease. This seems to suggest that rotator cuff disease may be the source of continued pain in athletes who have pain with overhead throwing and who are or are not treated with surgery.

Figure 7  The three subtypes of the type II SLAP lesion: A, anterior only, B, posterior only, and C, combined. (Reproduced with permission from Morgan CD, Burkhart SS, Palmeri M, Gillespie M. Type II SLAP lesions: three subtypes and their relationships to superior instability and rotator cuff tears. \textit{Arthroscopy} 1998;14:553-65.)

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Sensitivity and Specificity of Physical Examination Tests for SLAP Lesions by Location Subtype</th>
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<tr>
<td>Test</td>
<td>Anterior Lesions</td>
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<tr>
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Reproduced with permission from Morgan CD, Burkhart SS, Palmeri M, Gillespie M: Type II SLAP lesions: Three subtypes and their relationships to superior instability and rotator cuff tears. \textit{Arthroscopy} 1998;14:553-565.
tion, and internal rotation. The shoulder can be repaired with the patient in the lateral decubitus or beach chair position. The surgeon should have access to all quadrants of the shoulder and the table should be rotated to allow the anesthesiologist access to monitor the airway and intravenous drip.

The posterior diagnostic portal should be placed 2 cm inferior to the angle of the acromion and the junction with the spine of the scapula. An anterior portal is placed inferior to the acromioclavicular joint and joint assessment is performed. Cuff tear evaluation begins with visualization from the posterior portal. Subscapularis, biceps tendon, and anterior portions of the supraspinatus can be seen. From the anterior portal, the posterior inferior cuff can be further assessed. A capsulotomy can be performed anteriorly and anteroinferiorly (Figure 3). Returning to the posterior viewing portal, the capsule can be divided anteroinferiorly, followed by a division of anterosuperior adhesions adjacent to the labrum.

The arthroscope is placed in the posterior portal and directed in the subacromial space. After establishing inflow, a lateral portal is developed 3 cm lateral to the lateral bor-

der of the anterior acromion. The bursae are cleared so that the margins of the rotator cuff tear can be seen (Figure 4).

A grasping instrument or pituitary is introduced through the lateral portal to evaluate the mobility and quality of the tendons, and to reconstruct the shape of the tear. If the tendon quality is good, tissue mobility has been reestablished, and tear pattern has been determined, subacromial decompression can proceed. If the tear characteristics suggest irreparability, the treatment plan can be changed to include a modified decompression and biceps tenotomy or tenodesis (if pathologic changes are identified). Subacromial decompression should be performed without soft-tissue detachment or resection of the coracoacromial ligament (Figure 5). Decompression can be performed from the lateral portal, combined with the cutting block technique from the posterior portal. Further decompression of the distal clavicle is performed from the anterior portal while viewing the procedure from a posterior position.

Tendon repairs can be performed with viewing from the posterior or the lateral portal. The apex of the tear in L-shaped tears should be identified and the tear reduced with side-to-side sutures (Figure 6). In patients in whom delaminations have occurred, both superficial and deep layers of the tear need to be incorporated into the repair. These knots are tied to reduce the size of the hole, which Burkhart and associates have termed margin convergence.