SECTION 2

Trauma

11 Complex Trauma to the Shoulder Girdle, Including the Proximal Humerus, the Clavicle, and the Scapula: Current Concepts in Diagnosis and Treatment

12 Current Management of Posterior Wall Fractures of the Acetabulum

13 The Treatment of Periprosthetic Fractures

14 Controversies in the Intramedullary Nailing of Proximal and Distal Tibia Fractures

15 External Fixation of Tibial Fractures
11

Complex Trauma to the Shoulder Girdle, Including the Proximal Humerus, the Clavicle, and the Scapula: Current Concepts in Diagnosis and Treatment

Mark A. Mighell, MD
Armodios M. Hatzidakis, MD
Randall J. Otto, MD
J. Tracy Watson, MD
Benjamin J. Cottrell, BS
Michael C. Cusick, MD
Ioannis P. Pappou, MD, PhD

Abstract
Fractures to the shoulder girdle are common injuries in an aging population. Many techniques and theories lie behind the treatment of such injuries. Knowledge and understanding of current concepts for diagnosing and treating proximal humeral, clavicular, and scapular fractures and the theory behind them will help surgeons make informed decisions with regard to patient care.

Instr Course Lect 2015;64:121–137.

Traumatic injuries to the shoulder girdle are common in an aging population. To provide better patient care, it is helpful for orthopaedic surgeons to understand current concepts for diagnosis and treatment of these injuries.

Proximal Humeral Fractures
Proximal humeral fractures are the third most common fracture in elderly patients, following hip and distal radius fractures.¹ Based on the Neer criteria, 15% to 64% of proximal humeral fractures are displaced and may warrant surgical treatment.²⁻⁴ Open reduction and internal fixation (ORIF) has become a popular option for treating these fractures, and there has been increased use of angular stable implants.⁵⁻¹¹
Classification

Based on the Neer classification system, a proximal humeral fracture is displaced if one or more fracture lines—between the humeral head, the greater tuberosity, the lesser tuberosity, and the humeral shaft—are angulated more than 45° or displaced by more than 1 cm. Correct preoperative evaluation of the fracture configuration can be challenging, even for experienced surgeons. The AO and Neer classification systems for proximal humeral fractures have been shown to have poor interobserver reliability.12-16 Shrader et al15 recommended a head-centric classification scheme, and the learning points of radiographic interpretation outlined are designed to improve interobserver variability. One major drawback of the Neer classification scheme is a lack of varus/valgus alignment observed in three- and four-part fracture patterns. Furthermore, a distinction of displacement is lacking in the AO/Orthopaedic Trauma Association fracture classification system.17 Despite the shortcomings of the current classification schemes, when the varus/valgus configuration, the number of parts, and an evaluation of displacement are considered together, the treatment decision-making process is improved.

Blood Supply to the Proximal Humerus

Until recently, the ascending branch of the anterior humeral circumflex artery was thought to be the major blood supply to the humeral head.18-20 Extensive anastomoses between the anterior and posterior humeral circumflex arteries have been recognized. Recently, the role of the posterior humeral circumflex artery as a major contributor (64%) to the perfusion of the proximal humerus was identified in a magnetic resonance arthographic study of cadaver injection; both the anterior humeral circumflex artery and the posterior humeral circumflex artery provide important flow to the humeral head and the tuberosities.21 The blood supply of the proximal humerus is rich, with many anastomoses and small feeder vessels to the proximal humerus likely supplying blood to the fragments and the humeral head in many fracture patterns, particularly those that leave a long metaphyseal calcar segment with the humeral head.22,23 When a long calcar segment is absent, the valgus-impacted fracture often maintains a medial calcar soft-tissue hinge that can preserve the posterior or humeral circumflex artery capsular branches.23 Also, many proximal humeral fractures, despite being initially ischemic, do not progress to clinically relevant osteonecrosis, likely the result of collateral circulation and creeping substitution.22-24

Osteonecrosis

Osteonecrosis occurs when the blood supply to the humeral head is disrupted and not restored by stable healing and revascularization. The presence of osteonecrosis is often well tolerated in an anatomically healed proximal humeral fracture.25,26 Pain from osteonecrosis is exacerbated when there is concomitant malunion or nonunion of the tuberosities.25 Treatment with hemiarthroplasty is effective in patients who have humeral head collapse caused by osteonecrosis, as long as the greater tuberosity is near anatomically healed and a greater tuberosity osteotomy is not required to restore a near anatomic tuberosity-to-humeral-head relationship. If a tuberosity osteotomy is required, the results of hemiarthroplasty are often poor.27

Surgical Options

Open Reduction and Internal Fixation

Minimal Hardware Techniques

Suture fixation (or wire fixation) has led to good results in some studies of the fixation of two-, three-, and four-part fractures, particularly isolated greater tuberosity fractures and fractures with a valgus impaction pattern.28 In the hands of experienced surgeons, percutaneous pinning also has resulted in good outcomes.29-32 Harrison et al30 reviewed the intermediate-term results (minimum 3-year follow-up) of percutaneous pinning of 27 selected two-part, three-part, and valgus-impacted four-part fractures. All 27 fractures healed, and there was only a 4% rate of osteonecrosis at an average follow-up of 35 months. The osteonecrosis rate increased to 26% at an average follow-up of 84 months, with a 50% osteonecrosis rate in patients with valgus-impacted four-part fractures.

Although these techniques potentially preserve the important blood supply and soft-tissue attachment to the proximal humerus, they provide relatively weak fixation compared with plating and nailing.33-35 Percutaneous reduction and pinning, in particular, is technically challenging and has a steep learning curve. The potential complications include a loss of fixation (particularly in two-part surgical neck fractures), pin protrusion through the skin or into the glenohumeral joint, pin migration, pin tract infection, and iatrogenic neurovascular injuries.

Angular Stable Fixation: Locked Plate and Screw Fixation

Prior to the advent of angular stable plate fixation, standard compression plate fixation techniques were applied.
to displaced proximal humeral fractures. Unpredictable outcomes were observed in older patients with weaker bone. Currently, nonlocked plating has given way to locked plate and screw fixation for proximal humeral fractures. Multiple biomechanical studies have shown that fixed angle plating and divergent screw/peg fixation provide some of the most rigid constructs for proximal humeral fixation, particularly when combined with suture fixation of the rotator cuff and tuberosities to the plate.

The concept and the technique of locked plating have been well described. Empirically, there has been improvement over prior nonlocked plating techniques, but no direct comparison studies have been performed. Complications have been reported with a higher than expected frequency at relatively short-term follow-up. Complications have included osteonecrosis (4% to 33%), malunion and nonunion (33%), screw perforation through the articular surface of the humeral head (5% to 22%), loss of fixation or varus displacement (3% to 16%), impingement (7% to 11%), and infection (4% to 19%), with an overall reoperation rate of 6% to 44%. Complications and reoperations are more prevalent in older patients with comminuted fractures. Many of these complications occur intraoperatively, are technique dependent, and are mitigated by obtaining an anatomic reduction. A potentially devastating complication is glenoid erosion caused by perforation of locked screws (Figure 1).

Three concepts have led to improvements in locked plate and screw ORIF: refined surgical technique, complementary suture fixation, and restoration of medial calcar support to avoid varus alignment. To maximize the potential for healing, care must be taken to preserve the blood supply to the surgical neck, the tuberosities, and the humeral head. Gardner et al described a “bare spot,” a hypovascular zone on the lateral humerus with no anastomoses between the anterior humeral circumflex artery and the posterior humeral circumflex artery. The extended anterolateral approach allows a direct approach to this bare spot on the lateral proximal humerus. However, the main disadvantage of this approach is that the axillary nerve and its arborizing branches are at risk and must be carefully identified and retracted to avoid denervation of the anterior deltoid. In addition, splitting the deltoid for an extended length has the potential consequence of subdeltoid adhesions, although this has not been noted to be a major issue based on the current information available regarding the results of this treatment approach. Because of these potential issues, this chapter’s authors continue to use the deltopectoral approach for plate and screw ORIF of proximal humeral fractures, reserving the superior approach for intramedullary (IM) nailing.

Multiple authors have noted the importance of using suture fixation between the rotator cuff, the displaced tuberosities, and the plate. In many fractures, there is a variably displaced vertical fracture line that separates the posterior and central greater tuberosity from the anterior greater tuberosity at a varying distance from the bicipital groove. Because plates are placed laterally on the proximal humerus, this often places the plate directly on top of this fracture line, making screw fixation of the tuberosity parallel to the fracture line, rather than perpendicular to it. This can lead to a loss of fixation of the greater tuberosity because of substantial posterosmedial pull of the posterosuperior rotator cuff followed by secondary loss of fixation of the humeral head. When sutures are not used, displacement of the greater tuberosity from the construct can occur in both displaced and nondisplaced fractures. In a recent study, loss of greater tuberosity fixation with subsequent displacement was noted in 5 of 22 nondisplaced greater tuberosity fractures (23%) associated with two-part surgical neck fractures treated with a locked plate and screws. Supplemental suture fixation not only helps prevent loss of tuberosity fixation but also biomechanically supports the entire fixation construct and has led to good results with low complication rates in some series.

Medial calcar comminution with a lack of anatomic medial calcar and inferior humeral head fixation can lead to a loss of plate fixation, with resultant...
varus collapse, malunion, nonunion, and screw cutout into the glenohumeral joint.40,54 Locking screws placed subcortically in the inferior humeral head can minimize this risk.55-59 In addition, IM strut augmentation can be used in the acute setting with increased biomechanical strength and good reported short-term results.60-65 The potential complications of allograft fibula use include disease transmission, infection, and difficulty with revision treatment to arthroplasty after graft incorporation.

**Angular Stable IM Nail Fixation**

Early nail designs required an entry approach that disrupted the insertion footprint of the supraspinatus and likely led to shoulder pain and weakness after IM nailing of humeral fractures.66-68 Currently, an anterior insertion approach is preferred because this does not violate the insertion of the supraspinatus.66-69 This approach, combined with fixed-angle stabilization of the proximal construct, has led to predictable healing, low complication rates, and excellent clinical results in two-part surgical neck fractures.11,70 The long-term consequences of inserting a nail through the superior articular surface of the humeral head are unknown.70

Newer IM nailing devices have been developed with multiplanar proximal screws that lock to the nail via a semi-rigid nylon and polyethylene bushing.70 More widely angled proximal screws in these devices have been designed to provide improved tuberosity healing and humeral head support.74

**Technique for IM Nailing of Proximal Humeral Fractures**

The patient is placed in the beach chair position. True AP and lateral proximal humeral views are obtained using fluoroscopy. A percutaneous incision is made just distal to the acromioclavicular joint. A larger “strap” incision is used with release of the anterior deltoid and the coracoacromial ligament off the anterior acromion if open reduction maneuvers of the tuberosities and the humeral head are required.50 The nail is placed only after the fracture is provisionally reduced with suture cerclage.

Positioning of the arm in slight extension facilitates the proper entry angle into the proximal humerus. The arm is kept in maximum adduction to allow placement of the guide pin, instruments, and the nail. Tuberosity-specific screws are placed to compress the tuberosities and the nail, providing support for the humeral head segment.54 After fixing the tuberosities, all traction is removed, and the fracture is allowed to naturally impact. One or two distal screws are then placed by using a targeting jig. Adequate reduction is confirmed in orthogonal planes.

**Discussion**

Proper patient selection is critical, and near anatomic reduction is essential to optimize results. Candidates for ORIF are medically stable patients with displaced proximal humeral fractures who are active and have bone quality amenable to fixation. Humeral head impaction is not a contraindication to ORIF as long as stable anatomic fixation can be achieved. Percutaneous pinning, locked plate fixation, and angular stable IM nailing have become well-accepted techniques for fixation. Long-term longitudinal follow-up is important because osteonecrosis and posttraumatic arthritis often occur more than 2 years after a humeral fracture.

**Arthroplasty**

Advances in locked plate technology have improved fracture fixation and mitigated the need for hemiarthroplasty. When adequate reduction and stable conditions for revascularization can be obtained, osteosynthesis with preservation of the humeral head should be considered.71

Hemiarthroplasty is indicated for fracture-dislocations, head-splitting fractures (with greater than 40% involvement), locked posterior shoulder dislocations with greater than 40% head impaction, and three- and four-part fractures that are not amenable to ORIF or reverse shoulder arthroplasty (RSA). It is important to distinguish a valgus impacted four-part fracture from a classic four-part fracture-dislocation. Valgus-impacted fractures are best treated with ORIF.

The optimal time to perform a hemiarthroplasty for fracture is within 1 to 2 weeks after the injury occurred. Fractures that remain untreated for more than 4 weeks after injury are associated with poorer results. The reason for this is multifactorial but involves difficulty with tuberosity mobilization, placement, and healing.2-75

Modern fracture-specific stems were designed to promote tuberosity healing and stability by allowing the placement of bone graft and heavy sutures. These stems include a smaller body, suture eyelets, and ingrowth metals. Modular systems allow for conversion if revision is required. Krishnan et al6 reported that fewer tuberosities healed with conventional stems (38 of 58; 66%) compared with fracture-specific stems (89 of 112; 79%). A more recent study further supports the use of a specific low-profile fracture stem (allowing bone grafting), noting a reduced rate of
tuberosity complications after surgery and better anatomic and functional outcomes compared with a conventional standard stem (87% versus 45%).

The current body of literature suggests that using a fracture-specific stem will lead to a higher rate of tuberosity healing.

**Surgical Technique**

The surgical technique for hemiarthroplasty has been well described. The height of the prosthesis has been shown to directly affect tuberosity healing. Most low-energy, proximal humeral fractures do not extend into the medial calcar. When the medial calcar is intact, placing the inferior collar of the prosthesis against the intact calcar will restore the correct height of the proximal humerus. In fractures that are comminuted or involve the calcar, the top of the implant can be placed 5.6 cm ± 5 mm above the insertion of the pectoralis major tendon. Radiographically, restoration of the Shenton line of the medial cortex of the proximal humerus or the Gothic arch facilitates accurate reconstruction. The top of the prothetic head should be 7 to 10 mm above the reduced greater tuberosity.

The natural version of the proximal humerus has been shown in several studies to vary widely from 0° to 55°, with a mean of 29.8°. Version is assessed by comparing the transepicondylar axis of the distal humerus. Twenty degrees to 30° of retroversion relative to the forearm can be measured by using an alignment rod. Accurate version can be confirmed when the humeral head faces the glenoid in neutral rotation. Inaccurate version has been associated with tuberosity malreduction and poor outcomes.

Tuberosity reduction and healing are the most important determinants of shoulder function in hemiarthroplasty. For proper rotator cuff function, the tuberosities must heal to the humeral shaft and to each other. Proper suture technique also is critical to repair success. Sutures should be placed so that each tuberosity is secured to the shaft. The placement of a medial cerclage suture reduces interfragmentary motion (Figure 2). Bone graft should be used from the humeral head between the tuberosities and the prosthesis. In situations when bone cement is necessary, the cement should be placed distally in the humeral shaft with proximal impaction of additional bone graft and should never be placed under the tuberosities (Figure 3). A weep hole can be drilled distally to assist with this technique.

**Rehabilitation**

In general, sling use is recommended for the first 6 weeks and includes early passive motion only in the safe zone determined intraoperatively. In severely osteoporotic bone, the sling should be used at all times for 3 to 4 weeks. Shrugs along with elbow and wrist range of motion should begin immediately postoperatively. Formal stretching exercises and active assisted motion should be started at 6 weeks after surgery, with strengthening exercises at 12 weeks after surgery.

**Results**

The results of hemiarthroplasty reported in the literature remain variable. Mighell et al reported a mean forward elevation of 128° and external rotation of 43°. Krishnan et al reported a higher rate of tuberosity healing, a higher American Shoulder and Elbow Surgeons score, and greater motion.
when comparing fracture stems with conventional stems. Noyes et al\textsuperscript{83} found a high rate of complications, worsening functional outcomes and pain scores, and no improvement in range of motion. Antuña et al\textsuperscript{84} reported greater than 50\% unsatisfactory results, which were determined by using the modified Neer rating system.

Overall, the literature supports better results in younger patients who are treated acutely (within 4 weeks of injury). Pain relief has been more reliably reported than improvement in range of motion. Proper tuberosity reconstruction is the most important factor for a successful outcome.

**RSA for Acute Fracture**

Failure of the tuberosity to heal and tuberosity migration are the main causes of a failed hemiarthroplasty. Boileau et al\textsuperscript{72} recently reported that age older than 75 years, female sex, and the use of a conventional stem were risk factors for poor functional results and anatomic failure. Both RSA and hemiarthroplasty depend on tuberosity healing for best results; however, functional results (particularly forward elevation) in RSA appear to be less dependent on tuberosity healing. Despite this finding, a meticulous tuberosity repair technique is recommended in RSA; several studies have shown increased stability and rotation (internal and external) with tuberosity repair in RSA.\textsuperscript{85-90}

Recent literature has focused on direct comparisons between hemiarthroplasty and RSA for the treatment of proximal humeral fractures. Garrigues et al\textsuperscript{91} reported that RSA outperformed hemiarthroplasty with regard to motion and outcome scores. Cuff et al\textsuperscript{92} reported lower outcome scores, range of motion, and rate of tuberosity healing in hemiarthroplasty.

Varying complication rates of RSA and hemiarthroplasty have been reported in recent studies. A systematic review between RSA and hemiarthroplasty reported that the chance of a postoperative complication were four times greater with RSA.\textsuperscript{93} However, another systematic review found a similar complication rate between RSA and hemiarthroplasty.\textsuperscript{94}

**Discussion**

Good pain relief can be reliably provided with both hemiarthroplasty and RSA, but functional outcomes can be less predictable with hemiarthroplasty. The ideal patient for hemiarthroplasty is a younger patient with good bone quality and large tuberosity fragments. The patient should undergo surgical intervention within 2 to 4 weeks of injury; further delay may affect the overall outcome. RSA should be considered in older patients with poor bone quality and those with substantial tuberosity comminution or more chronic fractures. RSA may provide more reliable improvements in functional outcomes, particularly with regard to restoration of forward elevation.

**Clavicular Fractures**

Clavicular fractures are common injuries (2.6\% to 5\% of all fractures), with 80\% of these fractures occurring in the diaphysis. Traditionally, treatment has been conservative because influential, historic literature has reported high rates of healing with nonsurgical treatment.\textsuperscript{95,96} More recent literature suggests that the results of nonsurgical treatment are worse than previously thought.\textsuperscript{97-103}

Inferior outcomes and higher risks of nonunion are documented when there is significant displacement (>2 cm or no cortical contact) and other risk factors such as comminution (Z deformity), increasing age, female sex, and smoking.

In a systematic review of 2,144 clavicular fractures, a nonunion rate of 15\% was reported with nonsurgical management.\textsuperscript{104} Displacement and comminution were the primary risk factors contributing to nonunion. Surgical treatment resulted in a relative risk reduction of 86\% for nonunion.

Clavicular malunion is emerging as a clinical syndrome and is identified by shortening, deformity of the shoulder girdle (including the scapula), pain and fatigue with overhead activity, and weakness in strength testing.\textsuperscript{98,99,105} Osteotomy for malunion in these patients

---

**Figure 3** Illustration of proper placement of bone graft and bone cement. Bone graft should be used from the humeral head between the tuberosities and the prosthesis. When bone cement is necessary, the cement should be placed distally in the humeral shaft with proximal impaction of additional bone graft and should never be placed under the tuberosities.
improved their Disabilities of the Arm, Shoulder and Hand (DASH) scores by 32 points.

**Surgical Versus Nonsurgical Treatment of Midshaft Fractures**

In 2007, the first randomized controlled trial for clavicular fractures reported earlier healing rates (16 versus 28 weeks) and lower nonunion rates (3% versus 11%) for ORIF compared with nonsurgical management, such as a sling. In addition, surgical treatment resulted in better DASH scores and fewer symptomatic malunions. However, there was a 12% complication rate with surgical management—mainly related to symptomatic hardware.

In 2012, Virtanen et al reported on a randomized controlled trial of 60 patients with 1-year average follow-up. Nonunion rates were 0% for ORIF and 24% for the sling. Complication rates were 7% for ORIF and 12% for the sling, although none of the complications were major. The patients with nonunions (6) and malunions (2) in the sling group had worse DASH scores.

In 2013, Robinson et al reported a significantly reduced nonunion rate and better outcome scores after ORIF compared with nonsurgical treatment (1% versus 16%). When patients with nonunions were excluded from analysis, however, there were no differences in functional outcome between surgical and nonsurgical treatment. Improved outcomes resulted from the prevention of nonunion. Because of the cost and implant-related complications, the authors did not recommend routine primary ORIF for the treatment of displaced midshaft clavicular fractures.

**Surgical Indications**

Open or impending open injuries, neurologic or vascular compromise, unstable or displaced floating shoulder injuries, and posteriorly displaced medial clavicular fractures or sternoclavicular injuries constitute absolute indications for surgical treatment. The relative indications for surgical treatment include widely displaced fractures with shortening greater than 2 cm or significant comminution, unacceptable cosmesis, trauma accompanied by multiple injuries, predicted functional deficits, and painful nonunions or malunions.

**Surgical Techniques**

**Plate Fixation**

ORIF can be done with either superior or anterior-inferior plate positioning. Newer plate technology allows for precontoured plates that have a lower profile and allow for locking fixation if necessary.

The surgical approach should allow for cosmesis and prevent wound complications. A full-thickness skin and subcutaneous layer should be created down to the platysma, which is then incised longitudinally along the clavicle. The muscle insertions of the pectoralis major, the trapezius, and the deltoid on the clavicle are then released as required. This will allow for a full-thickness fascial layer over the plate at the time of closure.

Superior plate fixation allows the plate to be placed on the tension surface of the bone and requires less muscle origin release; anterior-inferior plating allows for reduced plate prominence and less plate irritation. In addition, screw length is increased, and there is less risk of neurovascular injury during drilling. Reconstruction plates are malleable to allow contouring to the patient’s anatomy, but they are weak compared with dynamic compression plates. Stand-alone, semitubular plates should be avoided.

Anatomically contoured plates fit most of the time and have a lower profile, which lessens the chance of plate removal, but they are more expensive. In cases of comminution, mini-fragment screws can be useful, allowing for reduction, lagging of a small butterfly fragment, and anatomic reduction. The plate is then placed as a neutralization plate (Figure 4).

The biomechanics of plating position are mixed. Some studies favor superior plating, whereas others favor anterior plating. The final results may differ in the same study depending on loading conditions.

**Intramedullary Fixation**

In clavicular fracture fixation, IM devices may result in shorter operating room time, less narcotic use, fewer complications, and less symptomatic hardware. However, IM devices are biomechanically inferior to plates, especially with increasing comminution. Cannulated screws, flexible nails, and clavicle-specific pins for the treatment of these fractures have been reported. The use of small diameter, smooth pins is contraindicated. A systematic review comparing plate fixation with IM devices for displaced clavicular fractures did not show any differences in functional outcomes or complication rates.

**Malunion/Nonunion**

Malunions and/or nonunions of clavicular fractures have adverse effects on functional results; risk factors have been discussed by several study groups. The goal in the
treatment of malunions and nonunions of the clavicle is to restore clavicular length and anatomy, which may require an osteotomy as well as a possible tricortical interposition graft. If possible, lag screws should be used to allow for compression across the fracture nonunion site.

Clavicular length is evaluated preferably on a CT scan of both clavicles or, at a minimum, on AP and oblique radiographs of both clavicles. If there is greater than 2 cm of shortening, then an osteotomy with interposition bone grafting should be considered to restore the appropriate length.

Plate fixation of clavicle nonunions and malunions provides high union rates and improvement in shoulder function. Plates and nails have been used successfully.\(^99,116-118\) This chapter’s authors favor plates because of their higher torsional rigidity. The improvement is comparable to the acute fixation of displaced fractures.\(^119\)

**Discussion**

Fracture nonunions are more common than initially reported, especially in displaced, shortened, or comminuted fractures. Malunions are common after nonsurgical treatment and can be clinically important. Nonsurgical treatment with a sling is recommended in patients with cortical contact and minimal shortening. Early surgical fixation gives good results and has been supported by randomized controlled trials in displaced fractures. Nonunion and malunion repair is successful at achieving healing (Figure 5).

**Scapular Fractures**

Most scapular body fractures are successfully managed nonsurgically, with early motion as pain allows because of the excellent blood supply and the
potentially large compensatory motion in the shoulder. Intra-articular (glenoid) fractures also can be managed successfully without surgery, provided articular congruity is maintained; arthroscopic and open techniques have been described. Controversy exists about what degree of extra-articular displacement constitutes a surgical indication. Surgical treatment promises sufficient restoration of shoulder girdle anatomy but has the added disadvantage of approach morbidity and surgical risks.

**Epidemiology and Associated Injuries**

Overall, scapular fractures are uncommon injuries that account for 3% to 5% of all shoulder girdle injuries. Associated injuries are encountered in approximately 90% of patients—ipsilateral extremity injuries (50%), thoracic injuries (80%), head injuries (48%), and spinal fractures (20%).\(^{120,122}\) Cervical spine injuries and brachial plexus lesions occur in 7% of patients with scapular fractures, and these injuries greatly influence the overall outcome.\(^{123}\)

**Classification**

Multiple classification systems for scapular fractures exist, but in 1995, Ideberg et al.\(^{124}\) described the most commonly used scheme based on an analysis of 338 scapular fractures involving the glenoid (Figure 6). The best method to accurately describe and document the complex three-dimensional deformity in scapular body fractures is three-dimensional CT, especially preoperatively and for research purposes.\(^{125}\)
The Super Shoulder Suspensory Complex

The super shoulder suspensory complex is an osteoligamentous ring composed of the glenoid, the coracoid, the clavicle, and the acromion process, as well as connecting ligaments (the coracoclavicular ligaments and the acromioclavicular joint capsule) (Figure 7). Interruption of two structures in this ring constitutes a double disruption, resulting in an interruption in the suspension between the axial and the appendicular skeleton.

Indications for Surgical Treatment

The most explicit recent surgical indications include medial displacement of the lateral border greater than 25 mm, shortening greater than 25 mm, angular deformity greater than 45°, concomitant intra-articular step-off greater than 3 mm, or displaced double disruption of the super shoulder suspensory complex.127 These indications are based largely on retrospective studies that documented poor shoulder function when those limits were exceeded123,127-142 (Table 1). With the exception of unstable and displaced glenoid fossa fractures, all surgical indications should be considered relative because of the lack of definitive proof regarding the benefits of surgery. Management must be individualized for each patient.

Nonsurgical Management

Minimally or moderately displaced scapular fractures that do not meet surgical indications can be managed successfully without surgery. A sling is used for the first 2 to 3 weeks until consolidation initiates; progressively unrestricted motion is encouraged. Physical therapy may be useful after consolidation for strength and endurance deficits. Progressive displacement is possible; therefore, vigilance with serial radiographs during the first 3 weeks after injury is recommended.143

Approaches for Surgical Treatment

There is no uniform approach that will successfully address all fracture patterns. The surgeon must be well versed in all the possible approaches and select the approach that best fits the fracture pattern. The ability of the Judet extensile posterior approach to provide wide exposure must be weighed against potential disadvantages, such as stiffness, hematoma or seroma, wound breakdown, and heterotopic ossification. Table 2 lists the typical indications for approaches to the scapula.

Benefits of Surgery for Extra-articular Malalignment

There is increasing recognition of dysfunction associated with scapular malunions; muscular deforming forces and the effect of gravity on the upper limb pull the lateral fragment anteromedially and distally. This results in displacement and malrotation of the glenoid fossa, affecting the glenohumeral joint and shoulder girdle function.

A 2013 systematic review attempted to examine if there was any benefit for the surgical fixation of 234 scapular neck fractures versus nonsurgical management of 229 fractures.144 The lack of direct comparison studies makes it difficult to draw firm conclusions because of heterogeneous fracture displacement, associated injuries, and multiple approaches. Nevertheless, some useful conclusions can be drawn. No statistically relevant differences in restrictions of day-to-day activities or the Constant Shoulder Score at the time point of follow-up could be seen. However, more patients in the surgical group were pain free during day-to-day activities.
### Table 1
**Studies That Produced the Current Recommendations for Surgical Treatment of Scapular Fractures**

<table>
<thead>
<tr>
<th>Fracture Type</th>
<th>Author (Year)</th>
<th>n</th>
<th>Surgical Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra-articular</td>
<td>Ada and Miller132 (1991)</td>
<td>8</td>
<td>Medial displacement &gt;1 cm or angular deformity &gt;40°</td>
</tr>
<tr>
<td></td>
<td>Khallaf et al130 (2006)</td>
<td>14</td>
<td>Medial displacement &gt;1 cm; angular deformity &gt;40°</td>
</tr>
<tr>
<td></td>
<td>Herrera et al133 (2009)</td>
<td>22</td>
<td>Medial displacement &gt;15 mm, angular deformity &gt;25°, articular step-off &gt;4 mm, or double lesion of the super shoulder suspensory complex</td>
</tr>
<tr>
<td></td>
<td>Jones et al127 (2009)</td>
<td>37</td>
<td>Medial displacement &gt;25 mm, shortening &gt;25 mm, angular deformity &gt;45°, articular step-off &gt;9 mm, or double lesion of the super shoulder suspensory complex</td>
</tr>
<tr>
<td>Double SSSC</td>
<td>Leung and Lam132 (1993)</td>
<td>15</td>
<td>Unstable shoulder girdle</td>
</tr>
<tr>
<td></td>
<td>Rikli et al133 (1995)</td>
<td>12</td>
<td>Unstable shoulder girdle</td>
</tr>
<tr>
<td></td>
<td>Egol et al134 (2001)</td>
<td>7</td>
<td>Displaced double lesion of the super shoulder suspensory complex</td>
</tr>
<tr>
<td></td>
<td>van Noort et al135 (2001)</td>
<td>4</td>
<td>Substantial clavicular displacement and a displaced scapular neck</td>
</tr>
<tr>
<td></td>
<td>Oh et al136 (2002)</td>
<td>10</td>
<td>Unstable shoulder girdle</td>
</tr>
<tr>
<td></td>
<td>Hashiguchi and Ito137 (2003)</td>
<td>5</td>
<td>Unstable shoulder girdle</td>
</tr>
<tr>
<td></td>
<td>Labler et al138 (2004)</td>
<td>17</td>
<td>Displaced neck fracture &gt;25 mm and/or reduction of the glenopolar angle &lt;30°</td>
</tr>
<tr>
<td>Intra-articular</td>
<td>Kavanagh et al139 (1993)</td>
<td>10</td>
<td>Displacement &gt;2 mm</td>
</tr>
<tr>
<td></td>
<td>Leung et al140 (1993)</td>
<td>14</td>
<td>Displaced fracture of the glenoid</td>
</tr>
<tr>
<td></td>
<td>Mayo et al123 (1998)</td>
<td>27</td>
<td>Displacement &gt;5 mm or displacement associated with subluxation</td>
</tr>
<tr>
<td></td>
<td>Adam141 (2002)</td>
<td>10</td>
<td>Displaced fracture of the glenoid</td>
</tr>
<tr>
<td></td>
<td>Schandelmaier et al142 (2002)</td>
<td>22</td>
<td>Displaced fracture of the glenoid</td>
</tr>
</tbody>
</table>

SSSC = super shoulder suspensory complex.

### Table 2
**Approaches for Scapular Fractures and Typical Indications**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Typical Fracture Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoplectoral</td>
<td>Anterior glenoid rim&lt;br&gt;Need for coracoid fixation&lt;br&gt;Associated proximal humeral fracture</td>
</tr>
<tr>
<td>Judet posterior extensile</td>
<td>Creation of large skin flaps and elevation of the musculature off the scapula may lead to increased surgical complications&lt;br&gt;Comminuted fractures&lt;br&gt;Late presentation with nascent malunion</td>
</tr>
<tr>
<td>Pillar approaches</td>
<td>Selective straight incisions over the lateral and medial pillars&lt;br&gt;Useful for most scapular body fractures in the acute phase</td>
</tr>
<tr>
<td>Windows</td>
<td>Small windows for the placement of plates with indirect reduction of fracture&lt;br&gt;Useful for acute fractures when no direct reduction is anticipated</td>
</tr>
<tr>
<td>Arthroscopy</td>
<td>May be used in conjunction with open surgery to better visualize a glenoid fracture. In certain fracture types (such as anterior rim or Ideberg type III), it may be used in isolation.</td>
</tr>
<tr>
<td>Combined</td>
<td>A combined anterior or arthroscopic and posterior approach may be required for complex fracture patterns with substantial intra-articular and extra-articular displacement.</td>
</tr>
</tbody>
</table>
Surgical treatment produced the following complications: postoperative stiffness (9 cases), surgically corrected insufficient reduction (2 cases), surgically corrected entrapment of the suprascapular nerve with postoperative hematomas and a need for revision surgery to evacuate (3 cases), heterotopic ossification (1 case), implant failures (2 cases), malunions (4 cases), and superficial wound infections (2 cases). The calculated overall rate for postoperative complications was 10.2%.

Discussion
The mainstay of treatment of most scapular fractures is nonsurgical. The surgeon must tailor the treatment of scapular body fractures to the degree of displacement and patient demands. Intra-articular glenoid fractures may require surgical treatment to restore joint congruity if intra-articular displacement is significant or in the presence of glenohumeral subluxation.

Summary
The shoulder is a complex region, and different diseases require various methods of treatment. The type of treatment chosen for a proximal humeral fracture relies on proper patient selection. Near-anatomic reduction is necessary for optimal results. Good pain relief and function can be reliably attained with shoulder arthroplasty; however, functional outcomes are directly related to surgical technique, particularly proper tuberosity management. For patients with clavicular fractures, nonsurgical treatment with a sling is recommended for fractures with cortical contact and minimal shortening. Early surgical fixation achieves good results, and repair of nonunion and malunion can achieve successful healing. Scapular fractures are usually treated nonsurgically, with the treatment tailored to the degree of displacement and patient preferences.

References


51. Robinson CM, Page RS: Severeiy impacted valgus proximal humeral fractures: Results of operative...


79. Boileau PG, Walsh G: The three-dimensional geometry of the proximal...


109. Collinge C, Deviney S, Herscovici D, DiPasquale T, Sanders R:


