33 Shoulder Girdle Injuries

Peter A. Cole and Ryan Horazdovsky

The shoulder girdle is a complex osseous chain consisting of the clavicle, scapula, and humerus, linked by ligamentous and capsular structures which collectively provide the origins and insertions for over twenty muscles which allow for coordinated movement of the upper extremity. Dysfunction therefore follows disruption or deformity in this linkage; however, since the sternoclavicular joint allows for 45° of motion, the acromioclavicular joint 20° of motion, and the glenohumeral joint up to 170° of motion in multiple planes, there is also more forgiveness for deformity than in any other anatomical region. This fact allows different interpretations of thresholds for operation based on the resources available in a particular underdeveloped hospital setting. Malunion in the clavicle or scapula, for example, is not generally as morbid as a malunion of the femur and tibia, and therefore the technical expertise must be balanced with the risks of surgery, and the baseline function of the patient. Nevertheless, if the goal is optimal function rather than reasonable function, and the likelihood of surgical success is great based on available expertise and management of risks, then there are plenty of reasons to operate. In this chapter, we will review diagnosis and management of the sternoclavicular, acromioclavicular joint, and glenohumeral joint, as well as the clavicle and scapula in the context of austere conditions.

33.1 Sternoclavicular Injuries

The sternoclavicular joint is a diarthrodial joint between the medial clavicle and the clavicular notch of the sternum. The sternoclavicular joint allows for motion in all planes and is where the majority of scapulothoracic motion occurs. Because of strong ligamentous support, injuries to the sternoclavicular joint are rare, representing only 3 % of shoulder girdle injuries [1]. A sternoclavicular injury is always a high-energy event, and, therefore, exploration for other injuries is paramount. Due to the posterior proximity of structures such as the great vessels, phrenic and vagus nerves, trachea, and esophagus, associated injuries should be suspected and diagnosed promptly.

The mechanism of injury can either be from a direct blow to the clavicle, or an indirect force applied to the shoulder. The sternoclavicular joint may sustain a simple sprain characterized by a non- or minimally displaced injury, in which there is a lack of deformity in the setting of pain

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and possibly swelling. This injury is stable, but frank dislocation is associated with complete ligament disruption which warrants surgical consideration [2]. Sternoclavicular dislocations are described according to the direction of dislocation, anterior or posterior. Anterior dislocations being more common because they result from a posterolateral blow to the shoulder.

A medial clavicular physeal fracture, which can displace anteriorly or posteriorly as well, mimics a dislocation and is common under the age of 25 as this the last epiphysis to close (23–25 years) [3]. Most of these injuries heal and remodel without surgical intervention [1].

33.1.1 Initial Management

Given the assumption of a higher-energy mechanism, the patient should be asked about difficulty breathing or swallowing, particularly upon recognition of a posterior dislocation. Hoarseness, persistent cough, or stridor should be documented. Patients may have distended neck veins and surrounding tissues secondary to local venous congestion (Fig. 33.1). Pain localized to the sternoclavicular joint is associated with swelling and possibly ecchymosis. There is usually a palpable and mobile prominence just anterior and lateral to the sternal notch in the case of an anterior dislocation, or a puckering of the skin with a sense of fluctuance in the posterior dislocation. Chest auscultation and a thorough neurovascular exam to the ipsilateral extremity are important.

Anteroposterior radiographs of the chest or clavicle are of limited usefulness when assessing for sternoclavicular joint injuries. A serendipity x-ray view of the shoulder is a 40° cephalic tilt view centered on the manubrium [3]. In this view, an anterior dislocation will be manifested with a superior appearing clavicular head. If a posterior dislocation is suspected, a computed tomography (CT) examination with 2 mm interval cuts is helpful to visualize the location and extent of dislocation, evaluate the retrosternal region for soft tissue injury, or elucidate a physeal injury. If a vascular injury is suspected, the CT scan should be combined with an arteriogram of the great vessels if possible.

33.1.2 Nonoperative Treatment

The majority of sternoclavicular injuries are anterior dislocations, and these should be treated nonoperatively with the expectation of a cosmetic manifestation of a large bump, resolution of pain, and restoration of good function [4]. Closed reduction can be attempted; however, the joint will not remain reduced. This

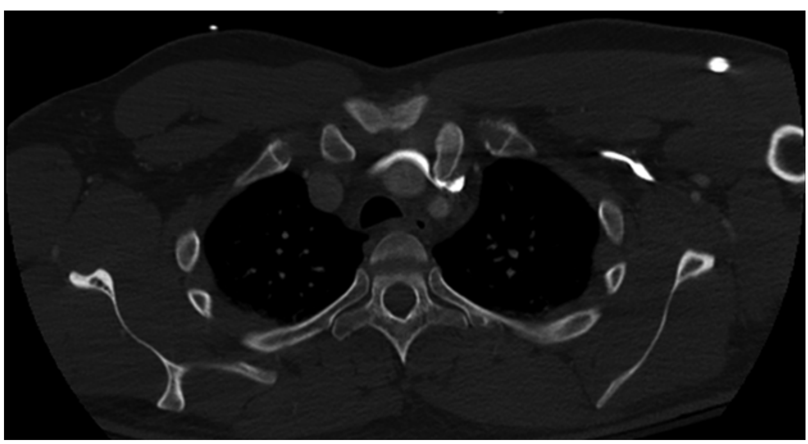

Fig. 33.1 Posterior sternoclavicular dislocation with impingement of posterior great vessels and significant venous congestion as evidenced by local soft tissue swelling. This patient was treated with an open reduction and suturing fixation through drill holes

expectant result also holds true for the medial clavicle physeal injuries that are displaced anteriorly.

33.1.3 Operative Treatment

Surgical intervention of anterior sternoclavicular joint dislocations is usually unwarranted given the high failure rates from open reduction [2]. A symptomatic posterior dislocation should undergo a manipulative reduction to unlock the retrosternal clavicular head to relieve impingement on critical structures and avoid late sequelae compression on critical structures [5].

A pointed bone tenaculum may be useful to grasp the head of the clavicle and pull it back to its proper manubrium relation (Fig. 33.2a). A roll between the shoulder blades while the patient is supine, in combination with lateral traction of the abducted arm, is a helpful adjunctive maneuver. A closed reduction maneuver is not always successful. Due to possible violation of critical structures in the mediastinum, it has been recommended to have anesthesia on hand to manage the airway and a thoracic surgeon on standby during the procedure for the unlikely event of disrupting a pseudoaneurysm or clot at the level of the great vessels.

Transfixing wires across the sternoclavicular joint is ill advised throughout the literature due to the reported problem of wire migration. In posterior dislocations or physeal injuries, a reduction of the dislocated distal fragment can be reinforced with heavy braided suture through drill holes in the distal fragment (Fig. 33.2b). A medial clavicle resection is the best option for symptomatic unstable posterior dislocations or painful chronic anterior dislocations. In such cases, the remnant scar tissue and capsule should be imbricated and tethered to the clavicle to help prevent instability.

33.1.4 Complications

Retrosternal dislocations are frequently missed, likely due to the lack of physical exam findings in the context of a multiply injured patient [6]. Missed or late diagnosis of associated injuries of the mediastinum and brachial plexus is well documented. Failure of fixation, hardware migration, and redislocation have also been reported after operative stabilization and are likely due to the high forces acting on this main articulation between the upper extremity and the axial skeleton [7]. Lastly, arthritic symptoms of the sternoclavicular joint are not uncommon, and many authors have described resection of the clavicular head to address refractory pain [8].

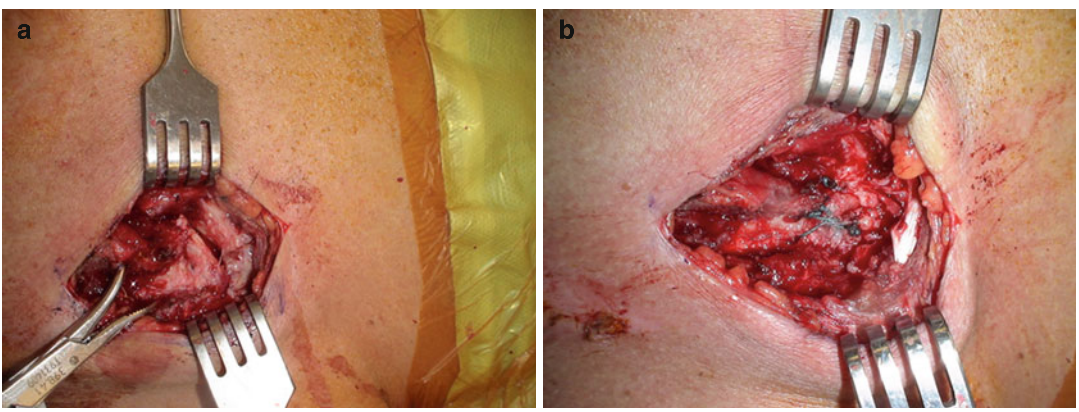

Fig. 33.2 (**a**) This is the medial clavicle grasped by a pointed bone reduction forceps to reduce it from its posterior dislocated position. To the right side of the incision next to the arrow is the heavy capsular tissue of the SC joint. (**b**) Is the repair of the unstable SC joint with drill holes through the clavicle repaired to the capsule with heavy braided suture

33.2 Acromioclavicular Joint Dislocation

The prominence of the acromioclavicular (AC) joint makes it vulnerable to dislocation from a direct blow to the shoulder, such as during a fall or lateral impact in a motor vehicle crash. The AC joint is a synovial joint that contains a fibrocartilage meniscus that is surrounded by capsule strongest at its superior and posterior margin [9]. The upper extremity is suspended in part by its connections to the lateral clavicle through the coracoclavicular (CC) and coracoacromial (CA) ligaments and AC joint capsule. The acromioclavicular AC joint dislocation occurs when there is at least partial disruption of these structures. This articulation may allow for up to 20° of rotation [10] and is further affected by the weight of the upper extremity as well as large muscular forces that act across a small surface area. These factors help to explain why internal fixation failures are common and why there are so many described techniques to repair fractures and dislocations of the AC joint: because, most have been associated with a high failure rate.

Distal clavicle fractures will be handled separately at the end of this chapter; however, much of the same discussion regarding the diagnosis and treatment of AC dislocations is relevant to the displaced or intraarticular distal clavicle fracture as well since fixation strategies are very similar and the use of distal clavicle resection for salvage.

33.2.1 Classification

Tossy et al. [11] and Allman et al. [12] developed classification systems for AC dislocations based on the degree of ligament injury and radiographic evidence of displacement and classified these as types I–III. A *type I* injury is a nondisplaced. The *type II* injury is incompletely displaced and associated with complete tearing of the acromioclavicular ligaments and sparing of the coracoclavicular ligaments. The *type III* dislocation represents complete disruption of the coracoclavicular ligaments and acromioclavicular joint capsule with superior displacement. Rockwood et al. [13] later described three additional types of more severe injury (types IV through VI) based on the direction as well as the amount of dislocation. Rockwood's *type IV* AC dislocation is complete, and the clavicle is displaced posteriorly. The *type V* injury is an extreme variation of type III, where the clavicle buttonholes through the trapezius into the subcutaneous tissue (High FIVE), whereas the *type VI* dislocation is dislocated inferiorly (Deep SIX).

33.2.2 Initial Management

Usually, there is history of a direct blow to the shoulder in which the patient presents with a swollen and painful AC joint. Evaluate the patient for other chest, neck, or brachial plexus injuries that may be associated, including the sternoclavicular joint since bifocal injury has been observed many times by the senior author (PAC). If a visual or palpable step off exists, or the distal clavicle feels unstable, then there is at least a type II injury. It is not uncommon for type I and II injuries to have a longer duration of pain than type III injuries due to residual articular contact and tethering of partially torn ligamentous structures. Ice relieves pain and swelling in the acute setting. A sling is useful for support of the upper extremity against gravity, but the joint cannot be maintained in a reduced position with any orthosis, including a figure-of-eight sling because of the deforming forces of the sternocleidomastoid and strap muscles of the neck.

Diagnosis can be confirmed by including both AC joints on one large x-ray cassette demonstrating relative displacement on one side, as well as anatomical variations of the AC facets.

33.2.3 Nonoperative Treatment

Type I and II AC injuries should be treated nonoperatively with the expectation of excellent short- to midterm results [14]. In the event that late, symptomatic AC arthrosis occurs, elective distal clavicle excision can predictably relieve pain and restore function [15]. Nonoperative management of type III AC dislocations is most appropriate in the austere environment as the collective weight of evidence reveals no clear benefit from surgical treatment [16, 17].

33.2.4 Surgical Treatment

33.2.4.1 Indications for Surgical Treatment

Surgical reconstruction should be considered in patients with type IV to VI AC injuries to prevent chronic dysfunction and pain. These injuries are associated with grotesque deformity which is uncomfortable and unacceptable by most reasonable standards (Fig. 33.3).

33.2.4.2 Surgical Techniques

Many surgical procedures have been described to repair AC dislocations, which belies the fact that until recently failure rates have been high. The strategies have included temporarily fixing the distal clavicle to the acromion, along with repair or augmentation of the CC ligaments. Each strategy can be employed in the acute or delayed setting. If a late reconstruction is done, it is usually combined with a distal clavicle resection.

The most widely known historical procedure is that described by Weaver and Dunn, in which the CA ligament is released from the acromion and transferred through the end of a resected distal clavicle [18]. The CA ligament plays a role in maintaining the concentricity of the humeral head, however, and its mobilization may lead to superior escape of the humeral head [19–21]. Today, some surgeons prefer either allograft or autograft tendon reconstructions to replace the CC ligaments. These are typically reinforced with a strong nonabsorbable suture such as Fiberwire® or Mersilene® tape preferably passed around the base of the coracoid process and then through a boney tunnel in the clavicle. In either case, fixation across the AC joint or into the coracoid base can be added to augment the soft tissue repair during healing. A 6.5 mm partially threaded screw from the clavicle to coracoid can be used for this purpose, so that with the lag effect, the Mersilene tape is off-loaded to help prevent erosion. K-wires and a tension band wire/suture technique have also been used. Plan for elective removal of the hardware 3–4 months postoperatively after CC ligament healing is important to prevent erosion of the bone and is paramount for fixation which crosses a joint.

Fig. 33.3 A clinical image of a patient with a type IV AC dislocation and the resultant grotesque deformity

The hook plate (Synthes USA, Westchester, PA) is gaining popularity as an option for acromioclavicular joint stabilization after dislocation [22–26]. If unavailable locally, a hook plate can be fashioned out of a 3.5 recon plate in the shop and sterilized prior to surgery. The plate is fixed to the cephalad border of the distal clavicle, and a terminal hook sweeps under the acromion so the clavicle is restrained from springing superiorly (Fig. 33.4a–d). To do this, the terminal hook should angle 90 and 90°, be at least 2.0 cm, and have a depth of approximately 1.5 cm for an average-sized individual, so the implant can make the turn posterior to the clavicle and under the acromion along its inferior surface (Fig. 33.4c). An attempt to repair the acromioclavicular joint as well as the coracoclavicular ligaments should accompany the use of the Hook Plate. These elements are torn, but approximation forms a scaffold for scarring back down. It is necessary to remove the plate at 3–4 months after surgery to prevent the complication of acromial osteolysis and possibly acromial fracture [23, 27–29] and impingement [30, 31]. The necessity of a second operation for hook plate removal may make this an inappropriate implant if a patient's ability to follow up is uncertain.

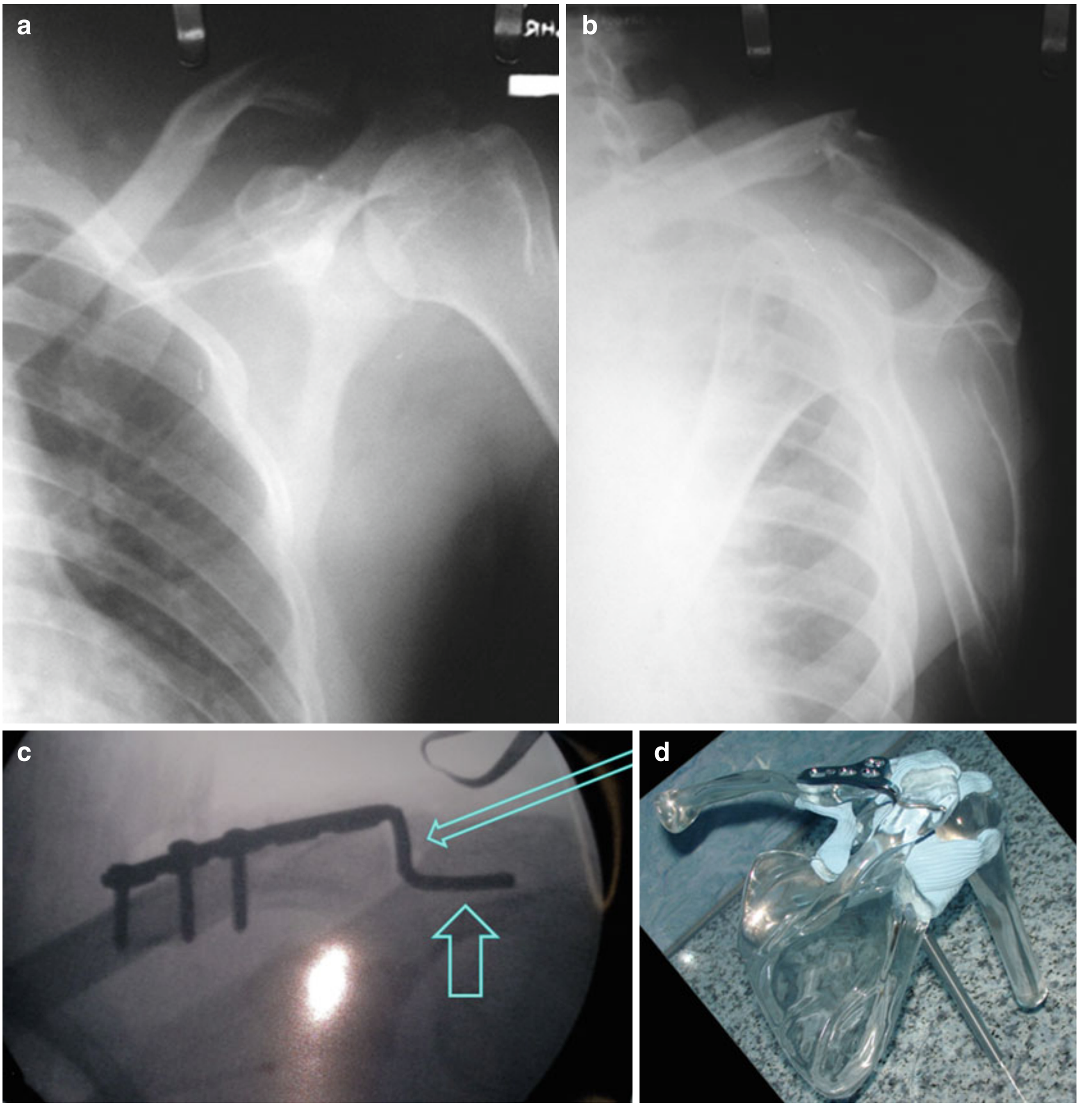

Fig. 33.4 (**a**) Grashey and (**b**) scapula Y radiographs showing a displaced and comminuted distal clavicle fracture. The surgeon opted to perform ORIF with a hook plate. (**c**) This hook plate can be fashioned in the hospital workshop out of a 3.5 mm recon plate preoperatively and sterilized for surgery (courtesy of Dr. Tul Bdr Pun, Tansen Mission Hospital, Nepal). It's "depth" from the distal clavicle to the inferior acromion should be approximately 1.5 cm (*thin arrow*) and the length of the hook no less than 2.0 cm (*fat arrow*). (**d**) Shown is a bone model which shows the hook plate design and its relationship to the clavicle and acromion

Another form of fixation which has become popular recently is the “tightrope” technique (Arthrex, Naples, FL, USA) which is an approximation of the clavicle to the coracoid using heavy braided suture and suture buttons which lie down on the clavicle and under the base of the coracoid (Fig. 33.5). Though this technology is prepackaged for surgery, and rather slick, it can be mimicked easily with heavy #5 braided suture and minifragment plates to serve as the buttons (Fig. 33.6).

The beach chair position is utilized draping the entire forequarter onto the neck. The entire extremity should be prepped to allow for

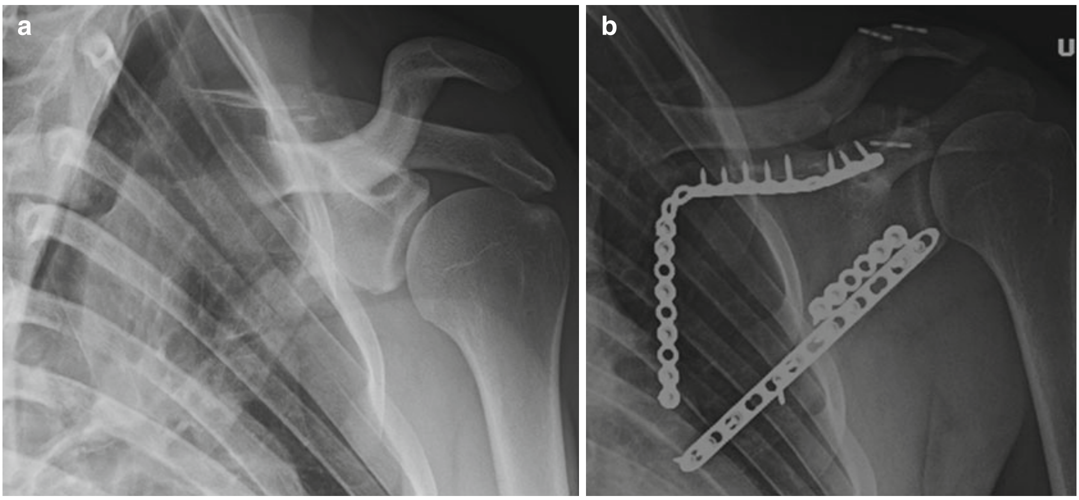

Fig. 33.5 (**a**) Grashey radiograph demonstrating an acromioclavicular dislocation as well as a comminuted extraarticular scapula fracture. (**b**) Postoperative image showing the reduced acromioclavicular joint with a Tightrope (Arthrex Inc., Naples, Florida) construct. This construct can be mimicked with heavy #5 braided suture and minifragment plates to serve as the buttons

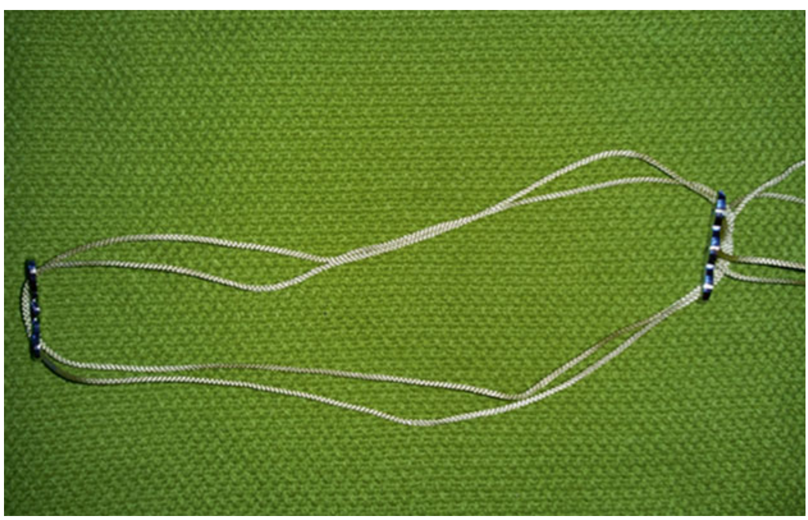

Fig. 33.6 Shows a heavy braided suture with minifragment plates which can be used to mimic the tightrope technique, which allows for execution in settings without the prepackaged technology. Minifragment plates can be used to reproduce the “tightrope” concept with the plates substituting for the buttons to dissipate stress on the clavicle and coracoid

manipulation of the arm aiding in evaluation of rotational nuances and reduction of the dislocation. A 6 cm incision centered over the anterior edge of the distal clavicle is made to expose the dislocated AC joint. The incision is made in Langer's lines and thus is vertically oriented, allowing for direct exposure of the torn ligaments and an adequate exposure of the coracoid. In distal clavicle fracture variants, a horizontal incision can be made over the distal clavicle and AC joint for easier exposure. Develop the flaps between the deltoid and trapezius for later closure of the deltotrapezial tissue plane. After the distal clavicle and AC joint are exposed, an evaluation of the articular integrity is made, removing pieces of detached articular cartilage if present. In the acute setting, the clavicle should be noted to reduce rather readily by an inferior directed force on it (in a type III), or pistoning the arm cephalad to meet the clavicle. The CC ligaments are then inspected and repaired if possible, but only after fixation of the AC joint with the technique of choice.

33.2.4.3 AC Ligament Tips

- Augmentation of a ligament reconstruction with some type of fixation to off-load the repair is prudent to take the stress off of any one point of fixation. A screw, such as the historical "modified Bosworth screw" described by Rockwood, or a partially threaded 6.5 mm screw, from the superior clavicle down into the coracoid, is stronger than Kirschner wires that cross the AC joint or a plate that traverses (bridges) the AC joint because the fixation is perpendicular rather than parallel to the deforming force. Any hardware which crosses a joint should be removed after 3–4 months.
- Due to the curved and slender shape of the distal coracoid, the surgeon should dissect along the proximal and posterior edge to appreciate the broader base into which fixation can be more securely attained. The screw vector from this position will be in a vector heading slightly lateral to purchase the bone of the glenoid neck. If the surgeon directs the drill directly inferior or medial, the bone is thin and difficult to purchase. If such screws are too distal on the coracoid, it is not uncommon to either fracture the coracoid or simply obtain poor purchase.
- Draping the arm free during the reconstruction of an AC joint (and clavicle fracture) allows aid for reduction and minimizes soft tissue stripping with repeated clamp applications.

33.2.5 Outcomes

The prognosis for type I injuries managed nonoperatively is excellent, whereas type II injuries have a good to excellent long-term prognosis [13]. A small percentage of patients, mostly with type II injuries, will develop symptomatic AC joint arthritis, requiring a distal clavicle resection [13, 32]. If conservative management of this fails, resection of the distal clavicle can be done by removing the distal 1.5 cm of bone, and results have generally been favorable [13, 33–35]. In such cases, after distal clavicle resection, a coracoclavicular ligament augmentation should be performed to mitigate the superior migration and instability of the distal clavicle.

33.2.6 Complications

Most of the complications related to surgery involve fixation failure resulting in recurrent prominence of the distal clavicle, instability, and pain. All described techniques can have hardware failure including slippage of Kirschner wires, cutout of CC screws, failure of grafts, or suture cutting through the distal clavicle or coracoid. Acromial erosion and fracture from retained hook plates, as well as fracture at the proximal end of the plate, are known. These various modes of failure underscore the technically demanding nature of the reconstruction.

33.3 Scapula Fractures

Scapula fractures represent about 5 % of all fractures about the shoulder girdle [36–42]. A study of 6986 fractures found that 52 (0.7 %) involved the scapula, which made it more common than distal humerus and distal femur fractures [43]. Scapula fractures are evidence that considerable energy has been imparted to the body. Large forces are required to cause a displaced scapula fracture because of the muscular envelope in which it lies, the mobility of the scapula on the thoracic cage, and surrounding musculoskeletal structures (proximal humerus, AC joint, and clavicle), which usually yield first [38]. Approximately 90 % of these patients have associated injuries highlighting the high-energy mechanisms generally involved [36, 39, 40, 44].

33.3.1 Initial Management

A thorough physical examination is important to detect these commonly associated injuries, particularly those that are life threatening. A majority of these patients have multiple broken ribs and resultant hemopneumothorax, 15 % have cervical spine injuries, 15 % have a traumatic brain injury, and 15 % have brachial plexus and peripheral nerve injury, and many of these injuries often mandate greater diagnostic and treatment urgency.

Radiographic evaluation of a scapula fracture includes three views of the shoulder, including an axillary view to assess the glenoid and its humeral relationship. Obtain an opposite shoulder AP radiograph to compare to the normal side if there is any doubt as to the interpretation of deformity. If available, a 3-D CT scan can be helpful to understand the deformity, take measurements, and place the surgical decision-making process in proper context. It is not uncommon to see worsening angulation and medialization over the first few weeks on radiographic examination, so serial x-rays are warranted [45].

33.3.2 Nonoperative Treatment

Moderate scapular displacement is well tolerated since the shoulder has such great motion in many planes. It is estimated that 90 % of scapula fractures are minimally displaced and therefore should be treated expectantly [40, 41, 46–54]. Treatment emphasizes early motion with symptom relief. After motion is restored in the first 4–6 weeks, therapy is directed at rehabilitating the rotator cuff and strengthening parascapular musculature.

If nonoperative treatment is chosen for severely displaced scapula fractures, there may be some consolation in the fact that it is almost reportable that a scapula fracture does not unite. And, if there is felt to be no expertise for scapula fracture ORIF, malunions can be dealt with at a later timing when an expert arrives to the mission hospital setting.

33.3.3 Surgical Treatment

Severe scapula fracture displacement is associated with symptoms of stiffness, pain, and dysfunction as evidenced by subsets of patients in many studies who have fared poorly.

A summary of our relative operative indications is based on educated conjecture and limited evidence in the literature on patients who have not fared well. The term relative indications is used, because it is reasonable to expect that any scapula fracture will unite, and maximizing function needs to be balanced with baseline function and future expectations.

Operative indications for open reduction and fixation of scapula fractures include [55–57]:

(a) Lateral border displacement (medialization) of >2 cm
(b) Angulation as determined by a scapula Y view of >45°
(c) Medialization plus angulation of >15 mm and 30°, respectively
(d) A glenopolar angle of <20°
(e) Displacement of a clavicle and scapula fracture of >1 cm (or complete disruption of an AC joint)
(f) Intraarticular step-off or gap of the glenoid >4 mm
(g) Displacement of the scapular spine, coracoid, and acromion process fractures greater than 1 cm

These indications are based on measurement techniques shown in Fig. 33.7.

33.3.3.1 Surgical Anatomy

The scapula is largely flat and triangular, with a thin body, surrounded by thicker borders that reflect the stresses from muscular origins and insertions. The scapular spine separates the superior and inferior fossae of the scapula, which are origins for their respectively named muscles. The subscapularis muscular origin occupies the concave anterior surface of the scapula.

The pear-shaped glenoid fossa has a peripheral margin covered by fibrocartilaginous labral tissue deepening the glenoid by 50 %. The intraarticular long head of the biceps tendon inserts at the supraglenoid tubercle.

33.3.3.2 Surgical Techniques

Most scapula fractures are best operated through some modification of the posterior approach of Judet or the anterior deltopectoral approach.

33.3.3.3 Posterior Approach

This is the approach best used for the majority of operative scapular fractures. The patient is placed in the lateral decubitus position, slightly forward facing for better access to the posterior scapular surface. A bump must be appropriately positioned on the contralateral side under the latissimus to protect the brachial plexus. The entire forequarter should be prepped and draped, including the arm, and the patient's neck superiorly, the vertebral column medially, and the latissimus fold caudally. Palpate the prominent posterolateral acromion and follow it medially along the spine of the

Senior Authors Operative Indications	
Intra-articular Fractures	≥ 4mm Step/Gap
	Open Fracture
	Symptomatic Malunion/Nonunion
Extra-articular Fractures	≥ 20mm Lateral Border Offset(LBO)
	≤ 22 degrees Glenopolar Angle(GPA)
	≥ 45 degrees Angulation
	Combination of ≥ 30 degrees angulation and ≥ 15mm and LBO
	Double disruption to the SSSC with ≥10mm at both lesions
	Open Fracture
	Symptomatic Malunion/Nonunion
Process Fractures	≥10mm Displacement
	Acromial depression
	Open Fracture
	Symptomatic Malunion/Nonunion

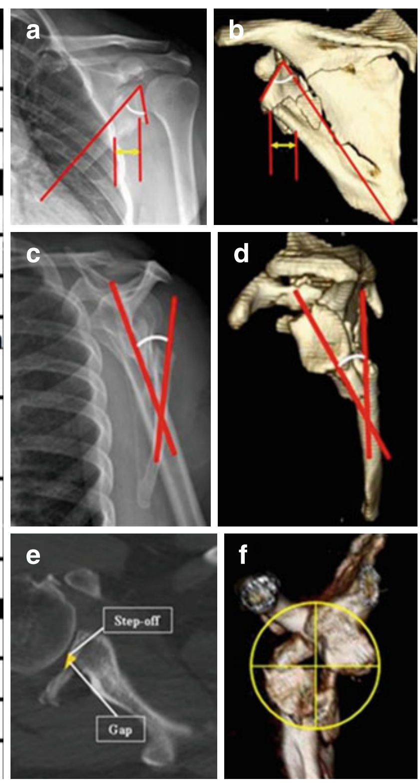

Fig. 33.7 Operative indications, x-ray and 3-D reconstructed CT images illustrating displacement measurement. (**a**, **b**) Measurements of lateral border offset (*yellow arrow*) and glenopolar angle (blue angle), which are measured on the Grashey x-ray view and 3-D oriented in the true AP plane. (**c**, **d**) Measurement of angulation (blue angle), which is measured on the scapula Y x-ray and 3-D CT views. (**e**, **f**) Intraarticular step-off and gap. These measurements can be performed on axial, sagittal, coronal, or 3-D CT reformats, depending on orientation of fracture line

scapula and then caudad along the medial border. Shuck the shoulder to feel the landmarks better.

A Judet posterior incision is made using these landmarks, with the horizontal limb slightly caudad to the scapular spine and the vertical limb 1 cm lateral to the medial border. Incise through subcutaneous tissue and then come directly down onto the bony ridge of the scapula spine around to the medial angle and down the vertebral scapular border. A generous incision allows for easy flap retraction and access to the lateral scapular border. The fascial incision along the acromial spine and medial border should provide a cuff of tissue to suture back to its bony origin at closure.

The muscle plane entered at the spine of the scapula is between the trapezius and the deltoid at the inferior margin. A Cobb elevator is used to elevate the infraspinatus from its origin in the infraspinatus fossa from the acromial superior border or at the medial vertebral border. At the vertebral border of the scapula, the intermuscular plane is between the infraspinatus and the rhomboids which are left attached. Look for a subtle fat strip to identify the important window between the infraspinatus and teres minor. This interval is developed to access the lateral border of the scapula, the scapular neck, and the glenohumeral joint.

33.3.4 Reduction Technique

The lateral border of the scapula and glenoid neck provide the best bone stock, so manual reduction maneuvers and fixation are best performed at these locations. Schanz pins can be used to manipulate main fragments.

A combination of clamps on the lateral and medial border and acromion is what it takes to perfect the reduction before a straight 2.7 mm plate application along the lateral border should be executed. Optimally, there should be at least four screws distal to the fracture along the lateral border and two in the glenoid neck to obtain balanced fixation for a simple fracture pattern (Fig. 33.8a). Contour a second plate to fit along the superomedial border where the plate often spans two fracture lines (Fig. 33.8b). Strive to place six screws on either side of the fracture in this region as each screw is typically 8–10 mm long with limited purchase. If these are not locking screws, then every screw should be angled in a different direction. In the most common fracture pattern extending from the lateral border to the superior angle, commonly two plates suffice for fixation (Fig. 33.8c, d).

33.3.5 Closure

Manipulate the shoulder to free adhesions, especially in patients whose care has been delayed. Repair the muscular origin with heavy, braided, nonabsorbable, no. 2 suture, through 2.5 mm drill holes in the scapular spine and medial border to prevent detachment during rehabilitation. A drain should be placed under the flap and exit proximal and anterior to the wound through a long subcutaneous tunnel to lessen persistent drainage due to dependency in the supine position.

33.3.5.1 Anterior Approach

A deltopectoral approach with the patient in a beach chair position is used for the fixation of anterior glenoid fractures, making an intraarticular assessment possible. An arthrotomy can be performed just lateral to the palpable glenoid rim just over the labrum. If there is articular comminution, then capsulotomy is mandatory, and work can be executed on either side of the capsule. A retractor can be placed on the posterior edge of the glenoid, to lever the humeral head laterally away from the glenoid articular surface. Reduction can be effected with a dental pick or shoulder hook, and provisional fixation with Kirschner wires is performed. Use screws (2.0–3.5 mm) and/or a mini buttress plate along the anteroinferior edge of the glenoid.

33.3.6 Scapular Tips

33.3.6.1 Straight Incision

A posterior glenoid or an intraarticular glenoid fracture with involvement of the glenoid neck, with minimal involvement or displacement of the scapular spine and vertebral border, can be approached with a simple straight posterior incision. Reduction maneuvers and fixation can then be achieved through the interval between the teres minor and infraspinatus.

33.3.6.2 Infraspinatus Tenotomy

If greater exposure to the glenoid fossa or superior glenoid is desired, an infraspinatus tenotomy can be performed. Leave a 1 cm of cuff insertion at the greater tuberosity for repair. This allows the musculotendinous portion of infraspinatus to be retracted off the superior glenoid and neck region for access to the glenohumeral joint. This maneuver is particularly helpful in large muscular patients with comminuted glenoid fractures.

33.3.6.3 Border Reduction

Manipulate the lateral border (distal fragment) with a shoulder hook through a drill hole. Medially, use pointed bone reduction forceps into small drill holes through the posteromedial aspect of the body, rather than clamping the medial border itself, to facilitate plate application without clamp removal.

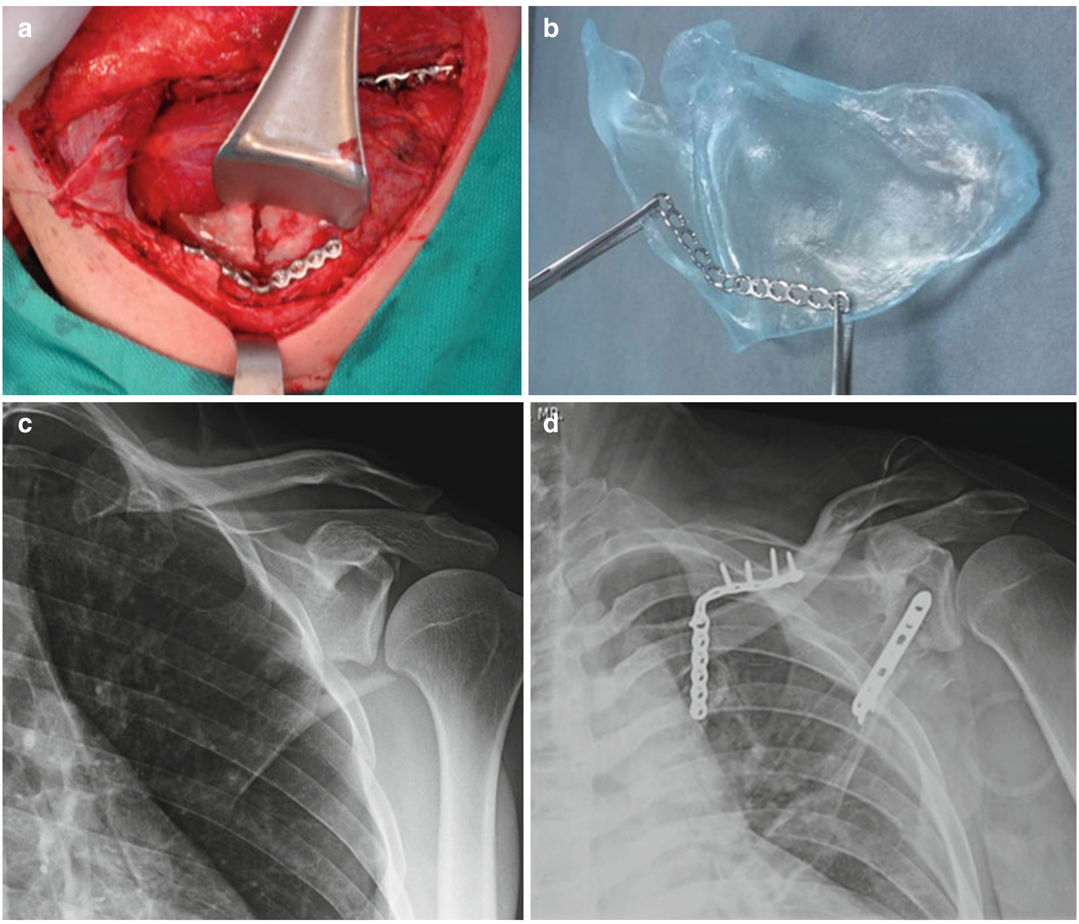

Fig. 33.8 (**a**) Intraoperative image of Judet approach with medial and lateral border plating. (**b**) Though a Judet incision was made, intermuscular windows were developed to access the borders for reduction and fixation. The lateral border is accessed through the interval between teres minor and infraspinatus. (**c**) An AP injury x-ray showing a highly displaced and medialized glenoid in an extraarticular scapula body and neck fracture. (**d**) A postoperative AP image showing a simple two-plate fixation strategy which was applied to allow for immediate active and passive range of motion

33.3.7 Complications

The most serious complications associated with scapular fractures pertain to accompanying injuries of adjacent and distant structures that occurred at the time of injury.

Complications from a fracture of the scapula itself are rare. A robust blood supply in this region likely contributes to nonunion and infection rates which are almost reportable. Other reported complications include malunion, glenohumeral degenerative joint disease, shoulder stiffness, and instability from poorly fixed glenoid fractures.

33.3.8 Rehabilitation

Postoperatively, after stable fixation of the scapula, a sling may be given to the patient for comfort, but immediate active and passive range of motion should begin on post-op day 1 as allowed by their pain. After one month, 3–5 lb. weights and resistance can be started, increasing gradually through the 2-month period at which time endurance activities begin. After 3 months, restrictions can be removed.

33.4 Scapulothoracic Dissociation

Scapulothoracic dissociation is a condition in which the forequarter dissociates from the thoracic cage from a traction injury. This injury almost never occurs with a scapula fracture and does not need to be suspected in the setting of scapula fractures since their injury mechanism is almost opposite – traction vs. lateral compression. The scapulothoracic dissociation has a high correlation with catastrophic injuries, including subclavian thrombosis or avulsion, plexus lesions, and cervical nerve root avulsion.

33.4.1 Initial Management

Physical exam reveals a boggy mobile posterior scapula region with swelling, pain, and at times ecchymosis. A detailed neurological exam and pulses of the extremity should be documented and recorded on a serial basis in the setting of detected lesions. Generally, appropriate workup should include an MRI or cervical myelogram to assess the integrity of the nerve roots and brachial plexus. Furthermore, a CT angiogram, or arteriogram, should be obtained to assess integrity of the subclavian vessels if asymmetric pulses are detected. These tests are generally not possible in an austere setting, and therefore careful documentation of serial exams is important. If there are dense neurologic lesions, then brachial plexus or nerve root lesions can be assumed, and the prognosis for recovery is poor, especially if there has been no return of function by 6 weeks post-injury. If there has been partial recovery detected in that time, then greater hope can be rendered to the patient, but expectations that it will take months to achieve ultimate results are important, and full recovery may never occur. Younger patients have much better prognoses, as do patients with partial lesions or lesions with evidence of early return of function.

A chest x-ray will reveal one scapula more lateralized from the midline than the other side. Measurements can be taken from the midline spinous processes for comparison. CT scans will reveal massive hematoma around the thorax and adjacent to the scapula.

In the developed world, an EMG and nerve conduction study would be performed to establish baseline nerve and muscle function between 6 and 12 weeks, which can be used as a basis for prognostication and surgical decision making, but this study is generally not available in an austere setting. Likewise, advanced nerve transfers for cervical avulsions and brachial plexus exploration and muscle transfers around the shoulder are done in only a few centers in countries with advanced medicine.

33.4.2 Surgical Indications

Salvage procedures should be executed for dense or complete brachial plexus lesions, because a “dead arm” or flail extremity is very morbid and will cause chronic pain in the neck. In these cases, there is little to no function below the elbow. This is a highly debilitating condition. The two salvage options for the austere setting which can provide great advantage to the patient include a glenohumeral disarticulation or a glenohumeral arthrodesis with an above-elbow amputation. The ladder is favored when motor function of the scapula is possible, because the stump can then be used as an adjunctive appendage.

33.4.3 Operative Management

The position for arthrodesis of the proximal humerus to the scapula should include 5° of abduction and 10–15° of forward flexion. Double plating should be performed across the joint, and iliac crest bone graft considered to augment the site of arthrodesis. The patient should be operated in the beach chair position with a large roll posterior to the shoulder to thrust the shoulder forward and help gain access to the spine of the scapula posteriorly.

An incision is executed one centimeter off the scapular spine and extending distally over the anterolateral proximal humerus down along the upper brachium over the deltopectoral interval. This interval is used to access the joint in order to denude all cartilage from the glenohumeral joint. Compression across the glenohumeral joint should be accomplished with a large fragment lag screw from the proximal humerus at the greater tuberosity into the glenoid neck. A large fragment plate and screws should then be used, extending from the humeral shaft across the glenoid neck where excellent fixation can be obtained. A second small fragment plate can be used along the scapula spine, extending down over the neck of the acromion to the humeral shaft adjacent to the first plate. This second plate provides a tension band for fixation which is a great mechanical advantage.

If there is no ability to protract or retract the scapula after many months, then the surgeon should proceed to a forequarter amputation. However, one of the advantages to saving the scapula includes shoulder symmetry for clothing wear which is not a small detail for the patient.

33.5 Fractures of the Clavicle

Clavicle fractures are the most common fracture, constituting 5–10 % of all fractures [58] and accounting for about 35 % of all injuries to the shoulder [59]. Functional results and symptoms are measurably improved in the correctly stabilized fracture, so the risk and reward ratio must be assessed based on the context of the hospital and OR setting. However, in the austere environment with limited resources, it must be remembered that reasonable function after clavicle fracture is possible in the setting of malunions and nonunions and that these conditions are rarely debilitating. In regard to operative vs. nonoperative management of displaced midshaft clavicle fractures – the clearest difference shown in a number of studies is a higher rate of nonunions in the nonoperative group [60, 61]. The number needed to treat is between 4 and 7 patients depending on the study to prevent a nonunion [60]. In the truly austere environment, a reasonable algorithm would be to treat nearly all displaced midshaft clavicle fractures with a sling and reserve operative treatment of clavicle fractures for open injuries, severe displacement, or symptomatic nonunions.

33.5.1 Initial Management

Pain and deformity localized to the clavicle is the typical presentation. Ecchymosis and tenting of the skin may be recognized and physical exam will detect bony crepitus. Inspection of the skin should rule out punctures or lacerations. Due to its proximity to the brachial plexus and the subclavian vessels, physical examination should also include neurovascular assessment, particularly in injuries associated with high-energy mechanisms.

Open wounds should be emergently managed. In the case of a distracted clavicle fracture, consider the diagnosis of scapulothoracic dissociation, which may be associated with vascular injury that demands immediate attention. Whereas orthogonal views of the clavicle have not been recommended, workup should include clavicle x-rays done at different angles, such as a 20° caudal and a

20° cephalic tilt view. A bilateral clavicle AP view allows measurement of relative shortening.

33.5.2 Nonoperative Treatment

The mainstay of treatment for proximal and middle one-third clavicle fractures which have bony contact is nonoperative. Middle one-third fractures should be followed closely until consolidation begins, because these injuries can displace substantially [62]. With distal third clavicle fractures, there will not be much displacement of the clavicle shaft if the CC ligaments are intact. Extraarticular fractures, displaced less than 1 cm, are treated with a simple sling or a sling-and-swath immobilizer for comfort.

Intraarticular distal clavicle fractures most often also warrant nonoperative treatment, particularly if comminuted, but the patient should be warned of the possibility of arthritic symptoms if there is step-off or comminution at the AC joint. A distal clavicle resection can be performed later if arthrosis ensues. In children, 2 weeks of relative immobilization is required before callus forms and pain resolves, a period which is longer by a couple of weeks in the adult.

Though some orthopedists favor a figure-of-eight sling [63–65], it is generally well accepted that this modality offers no advantage over simple support with a sling. Comparative studies have demonstrated no difference in shoulder function, residual deformity, or time to return to full range of motion with either modality [64, 66]. Evidence also suggests that patient satisfaction is higher with simple sling treatment [66]. The figure-of-eight bandage or sling may be discontinued at 2 weeks for young children and 4 weeks for adults [67].

33.5.3 Indications for Surgical Treatment

The clearest indication for surgical treatment is the case of an open fracture, which requires irrigation, debridement, and fixation. The most common form of internal fixation is with plate and screws. Fractures lateral to the coracoid may be associated with torn CC ligaments, in which case the shaft of the clavicle displaces proximally, while the distal fragment remains anchored to the acromion and coracoid. This injury variant is associated with a higher rate of nonunion and consideration should be given to open reduction internal fixation in displaced distal clavicle fractures.

Another relative indication for surgery is medialization of the distal clavicle by more than 2 cm, as indicated by the amount of overriding (shortening) of the shaft. McKee et al. documented poorer performance on endurance testing, as well as on a validated outcome test, in patients with more than 2 cm of shortening and showed that operative correction of malunions can improve function and strength [68]. The Canadian Orthopaedic Trauma Society performed a randomized controlled trial comparing nonoperative treatment to plate fixation in patients with a completely displaced, middle third clavicle shaft fracture with no bony contact [69]. Operative treatment was associated with better outcomes as assessed by function and strength, complications, malunion, nonunion, and patient satisfaction [69].

Functional results and symptoms are measurably diminished from the correctly stabilized fracture, so the risk and reward ratio must be assessed based on the context of the hospital and OR setting. However, in the austere environment with limited resources, it must be remembered that reasonable function after clavicle fracture is possible in the setting of malunions and nonunions and that these conditions are rarely debilitating. In regard to operative vs. nonoperative management of displaced midshaft clavicle fractures – the clearest difference shown in a number of studies is a higher rate of nonunions in the nonoperative group. The number needed to treat is between 4–7 patients depending on the study to prevent a nonunion [60]. In the truly austere environment, a reasonable algorithm would be to treat nearly all displaced midshaft clavicle fractures with a sling and reserve operative treatment of clavicle fractures for open injuries, severe displacement, or symptomatic nonunions.

33.5.4 Surgical Treatment

33.5.4.1 Surgical Technique

Make a straight horizontal incision approximately 1 cm inferior to the palpable clavicle, centered over the fracture. In the subcutaneous tissue, there are two or three supraclavicular nerves, which can be preserved; however, morbidity from their ablation is nearly absent and limited to a patch of numbness.

After the superficial dissection, the platysma is divided along the anterior border of the clavicle. A supraperiosteal dissection of the anterior or superior margin of the clavicle is performed and the fracture appreciated. In simple oblique fractures, reduction is easily obtained with a pointed bone tenaculum, followed by a 2.7 or 3.5 mm lag screw placed perpendicular to the fracture. A clamp is strategically placed out of the way of the proposed plate position. A neutralization plate is then applied with at least six cortices of purchase on either side of the fracture, though in comminuted patterns, a longer plate is desired and the zone of comminution bridged with butterfly fragments simply approximated to the plate with #1 braided suture. A 3.5 mm dynamic compression plate is preferred for its strength in most, though a 2.7 mm dynamic compression plate or 3.5 mm reconstruction plate may be sufficient in smaller or younger patients.

Fracture reduction is particularly difficult when there is significant intercalary comminution. Rather than attempting to put together a comminuted segment, which will promote devitalization of the bone and compromise blood supply, a bridge plate should be used. Manipulation of the shoulder through the arm can be used to reduce the lateral fragment. Fixation can be achieved without "touching" the fracture. Fixation is then performed with no less than six cortices of purchase on the proximal and distal fragments.

Some authors have reported favorable results with intramedullary fixation [70–72]. Obtain fracture reduction and then displace the fracture and predrill the clavicle each way with a 2.5 mm drill to ream the medullary canal. Then starting at the fracture, drill a 3/16 threaded pin laterally until it exits the skin. Move the drill to the opposite end of pin and continue to advance pin by drilling in reverse until pin clears the medial fragment enough to reduce fracture. Observe visible portion of pin to determine depth into medial fragment if C-arm is not available with a goal of 3–5 cm of pin on each side of the fracture. Cut off pin at lateral clavicle leaving enough to grab for removal 3 months later.

The same procedures have been employed for AC disruption can be employed for distal clavicle fractures, specifically those in which the shaft displaces superiorly due to ruptured CC ligaments (see *AC section*). The fixation and repair challenges of distal clavicle fractures, regarding maintaining reduction, are similar to the surgical challenges of AC dislocations due to the deforming force of the sternocleidomastoid muscle on the proximal clavicle shaft. However, in the case of distal clavicle, eventual bony union helps to maintain reduction after plate removal.

33.5.5 Clavicle Tips

- The push-pull technique is a helpful reduction technique for clavicle fractures treated in a delayed fashion. A blocking screw is placed on the medial aspect of the clavicle and the plate is fixed to the lateral shaft. A lamina spreader is then placed between the plate and blocking screw and leverage is used to disrupt callus and bring the clavicle out to length with reduced periosteal stripping. Do not over-lengthen because this can promote nonunion.
- Prep the arm free, because manipulating the arm can greatly simplify obtaining a reduction without directly handling the fractured site.

33.5.6 Complications

Patients managed nonoperatively should be counseled to anticipate a lump in the region of the fracture if treated nonoperatively. Earlier reports of nonunion rates were less than 1 %, although more recent studies show higher rates in the range of 15 %, possibly reflecting different fracture patterns from higher-energy mechanisms [58, 67]. Studies have shown higher nonunion rates for the distal clavicle in the range of 30 %. Identified risk factors for nonunion include displacement, advancing age, female, and displaced distal clavicle fractures [73]. Complications associated with nonunion and symptomatic malunion include limited function of the shoulder, neurological symptoms, thoracic outlet syndrome, and arterial ischemia, though the latter is very rare [74–76].

The clavicle superficial location causes high rates of symptomatic hardware necessitating implant removal. Wait for a minimum of 1-year post-fixation before removal is performed on a united clavicle. Less common complications include infection, implant failure, and nonunion. The greatest risk for catastrophic injury is medially since at times the subclavian vessels can be touching the posterior surface of the clavicle. Newer implants and techniques have reduced the rates of pin migration and soft tissue breakdown for intramedullary devices, but these alarming complications have been widely reported in the literature both in the developing and developed world.

33.5.7 Follow-Up in Shoulder Girdle Injuries

Nonoperatively managed patients with scapula and clavicle fractures must be followed closely until consolidation begins, because these injuries can displace substantially in the first 3 weeks [62]. If they do displace, it is possible that operative intervention may become warranted. We routinely see both our operatively managed patients at 2, 6, and 12 weeks postoperatively, whereas when managed nonoperatively, x-rays are obtained each week for the first three. Patients with limited motion are more common after brachial plexus injury, a head injury, a halo vest for spine injury, or complex associated fractures of the ipsilateral extremity. This is an excellent time for a manipulation under anesthesia to jump-start the motion for the patient. If range of motion is not regained during this period, the patient may have permanent loss of function.

After nonoperative management, in the first 2 weeks, patients are encouraged to perform pendulum activities, but after this juncture, passive and gentle active-assisted range of motion should be encouraged up to the sixth week. Pulleys and push-pull sticks powered by the opposite extremity, and supine-assisted motion, are effective modalities. Ipsilateral elbow, wrist, and hand exercises using 3–5 lb. weights (on a supported elbow) are encouraged. These exercises will lessen upper extremity muscular atrophy and promote edema reduction. After 6 weeks, the patient can then begin more aggressive active range of motion and light lifting, starting with 3–5 lb. repetitions, advancing as tolerated. Good function is usually restored by 3 months post-injury, at which time restrictions can be lifted.

In the operative patient properly stabilized, immediate passive and active range of motion is begun after surgery and ramped up with a goal of full motion after a month. In the second month, 3–5 lb weights and resistance is begun, ramping up to full strength in the 2–3-month time frame. Restrictions are lifted after 3 months.

33.6 Shoulder Dislocation

The management of shoulder dislocation is an important consideration for medical caretakers in the developing world setting because it is a common injury. The rehabilitation from this injury differs from the above regimen because longer periods of immobilization are necessary to allow for capsular healing and stability to be restored. The patient with an acute shoulder dislocation presents with pain, swelling, deformity, and decreased range of motion. Perform a thorough neurovascular examination. A most often transient injury to the axillary nerve is present in 5 % of patients. A posterior dislocation will present adducted and internally rotated with limited external rotation. An anterior dislocation will present externally rotated with a block to internal rotation. Obtain a trauma series of the shoulder including an AP of the shoulder, scapular Y, and an axillary view to demonstrate the humeral head is located within the glenoid. Missing a posterior dislocation is common due to failure to obtain an axillary view. The shoulder dislocation must be diagnosed and reduced to prevent permanent disability.

Injecting 10 cc of 1 % lidocaine into the glenohumeral joint and waiting 5 min before a reduction attempt while gently applying traction is an efficient, effective, and safe way to address this problem. This technique has been successful for dislocations presenting a week out. Alternatively, the patient can be sedated. Traction counter traction is necessary to reduce these injuries. An assistant holds a sheet passed through the axillae while traction is applied to through the forearm. It can be helpful to have another assistant pass a towel around the proximal humerus to apply lateral traction while directly pushing on the humeral head in the desired lateral and anterior/posterior direction to disengage the humeral head from the glenoid. For posterior dislocation, traction is applied with the arm held in adduction and internal rotation. With reduction, there is a palpable or audible clunk, decrease in pain, and improved passive range of motion. Post-reduction assess the stability of the shoulder and then obtain x-rays to confirm reduction and evaluate for fractures of the glenoid or humeral head. If closed methods fail, the patient will require an open reduction. Patients younger than 40 are immobilized for 3–6 weeks in a sling while those older than 40 are immobilized for 1–2 weeks.

Because of the lack of access to appropriate facilities and lack of education, patients not uncommonly present with chronic dislocations which manifest in a stiff, painful, dysfunctional shoulder. Posterior dislocations are characterized by an internally rotated shoulder which is stuck, and anterior dislocations are characterized with an inability to internally rotate. Forward elevation is minimal and the limited arc of motion is overcompensated by the patient's scapulothoracic motion.

These circumstances can be managed with a proximal humeral resection through a deltopectoral approach. The goal of this surgery is to provide pain relief and a better arc of motion, though even this is limited to below shoulder plane function. Nevertheless, patients are much happier with this enhanced arc of motion which is often enough for employment opportunities or the simple abilities needed to provide for a family.

The deltopectoral interval is developed down to the subscapularis and capsule. This is often a mass of scar, which should be incised and tagged with heavy braided suture to allow for open access to the glenohumeral joint. The scar tissue needs to be resected, as well as fracture remnants from the anterior or posterior glenoid (bony Bankart fragments). The dislocated humeral head needs to be resected with an osteotome and rongeur until it is evacuated from its dislocated position. A "joystick" will never be possible to simply pop the humeral head out because of chronic scarring. A piecemeal dissection will be necessary with the goal to leave the greater and lesser tuberosities intact (Fig. 33.9a). Once the humeral head is resected at the anatomical neck, the remnant capsule and scar tissue are imbricated with heavy braided suture. If the greater tuberosity is taken, the supraspinatus is advanced through a drill hole at the surgical neck to provide an anchor for healing. The reattachment of the supraspinatus and infraspinatus is important for upper extremity function, and these steps are critical for best success in this procedure. The pseudo-joint now is not under great tension and mobility is now possible.

A postoperative sling and early pendulum exercises, advancing to gentle passive- and active-assisted range of motion, are encouraged as allowed by symptoms. No resistive activities with weights are done until 6 weeks postoperative. All restrictions can be removed at 3 months.

33.7 Tutorial

A 26-year-old male laborer was involved in a motorcycle accident in a remote part of Nepal. He presented to a mission hospital one week later with left shoulder pain. On exam he had intact skin, tenderness to palpation, significant deformity, pain with range of motion, and intact

Fig. 33.9 (**a**) X-ray showing a chronic anteroinferior shoulder dislocation resulting in an irreparable Hill-Sachs lesion. (**b**) Shoulder radiograph obtained after shoulder resection arthroplasty. (**c**) This patient had a functional and painless arc of motion below the 90° shoulder plane which allowed him to effectively return to work as a motorcycle mechanic

motor, sensation, and normal pulses distally. X-rays revealed a significantly displaced distal clavicle fracture. Risk, benefits, and alternatives were explained and the patient elected to proceed with open reduction and internal fixation with hook plate with a planned plate removal 3 months after initial operation. The patient healed, had removal of hardware, and was able to return to work (Fig. 33.4).

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