Acute Fractures of the Upper Limb

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Carina Cohen, Horácio Sousa, Nuno Sevivas, and Guillermo Arce

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The frequency of football injuries reported in medical literature is estimated to be approximately 10–35 per 1000 playing hours. During football tournaments injuries of the lower extremity are almost ten times more common than upper extremity lesions. However, shoulder lesions are seldom seen if we consider the total of injuries reported [1]. In the FIFA World Cup, one of the most popular sporting events, a total of 104 injuries were reported: lower extremity accounted to 65.4%, followed by head/neck in 18.3%, upper extremity 9.6% (10 reports), and trunk in 6.7% [2].

Moreover, if we consider a total of 3944 injuries reported from 1546 matches in the World Football Tournaments (1998–2012), most injuries affected lower extremity (n = 2706, 70%), followed by injuries to the head and neck (n = 577, 15%), trunk (n = 302, 8%), and upper

C. Cohen (✉)
Shoulder and Elbow division of CETE (Centro de Traumatologia do Esporte), UNIFESP (Universidade Federal de São Paulo), São Paulo, Brazil

Instituto Cohen, São Paulo, Brazil

Hospital Israelita Albert Einstein, São Paulo, Brazil
e-mail: cacohen18@gmail.com

H. Sousa
Department at Clinica da Sé, Madeira University, Funchal, Madeira, Portugal
e-mail: horaciosousa@netmadeira.com

N. Sevivas
Life and Health Sciences Research Institute (ICVS), School of Health Sciences, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal

ICVS/3B's – PT Government Associate Laboratory, Braga/Guimarães, Portugal

Orthopaedics Department, Hospital de Braga, Braga, Portugal

Clínica Espregueira-Mendes, FIFA Medical Centre of Excellence, Estádio do Dragão, Porto, Portugal
e-mail: nunosevivas@gmail.com

G. Arce
Department of Orthopaedic Surgery, Instituto Argengino de Diagnóstico y Tratamiento, Buenos Aires 1425, Argentina
e-mail: guillermoarce8@gmail.com

J. Espregueira-Mendes et al. (eds.), *Injuries and Health Problems in Football*,
DOI 10.1007/978-3-662-53924-8_28

extremity (n = 269, 7%) [3]. Although shoulder injuries are relatively rare, once they occur, they produce a significant functional impairment that can limit performance since football is a demanding activity, in relation to increased velocity of playing and blocking and frequency of field hitting, especially for goalkeepers.

In general, traumatic dislocation of acromioclavicular and glenohumeral joints are the most frequent lesions of the upper extremity in football, but fractures may also happen and are the most common injury of the forearm and the second most common injury to the wrist [4].

Along this chapter we focus on the acute upper extremity fractures that might be seen in football. They usually occur during falls onto an outstretched arm (FOOSH), and goalkeepers may also be injured during collisions when attempting to catch the ball.

28.1 Scapular Fractures

Scapular fractures are rare, accounting for 3–5% of shoulder girdle fractures and 1% of all fractures [5]. Scapular fractures generally result from injury force through either direct impact or lateral compressive injury but can also be caused by indirect forces via axial transmission through the humerus or secondary to muscular or ligamentous traction. In football they are very uncommon since they usually result from high-impact trauma and are associated with serious bony or soft tissue injuries in 80–95% of cases, including pneumothorax, hemothorax, pulmonary injuries, and spinal injuries. Fractures are classified according to the anatomic area and are grouped into intra-articular glenoid fossa and rim, extra-articular glenoid neck, acromion, coracoid, and scapular body (Fig. 28.1).

More than 90% of scapular fractures are nondisplaced or minimally displaced and do well with conservative management; however, a specific subset of fractures may lead to poor outcomes after conservative treatment.

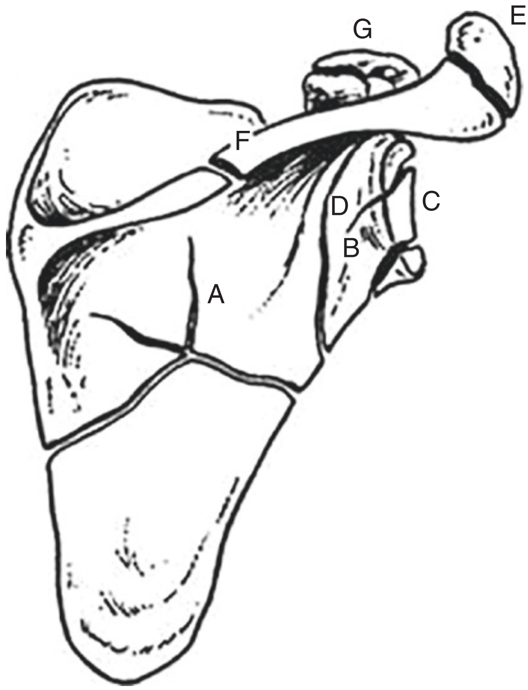

Fig. 28.1 Anatomic classification (Zdravkovic and Damholt) (**a**) scapula body, (**b**, **c**) glenoid, (**d**) scapula neck, (**e**) acromion, (**f**) scapula spine, (**g**) coracoid
Type I: Scapula body
Type II: Apophyseal fractures, including the acromion and coracoid
Type III: Fractures of the superolateral angle, including the scapular neck and glenoid

28.1.1 Intra-Articular Glenoid Fractures

Intra-articular glenoid fractures generally occur by transmission of force through the humeral head to the glenoid cavity. They are classified according to the Ideberg system with the Goss modification, which includes six fracture types (Fig. 28.2).

Type I fractures are true glenoid rim fractures, but types II–VI are glenoid fossa fractures with varying extension through the scapular body. Glenoid fractures with minimal displacement and angulation are treated conservatively in 90% of cases. [6].

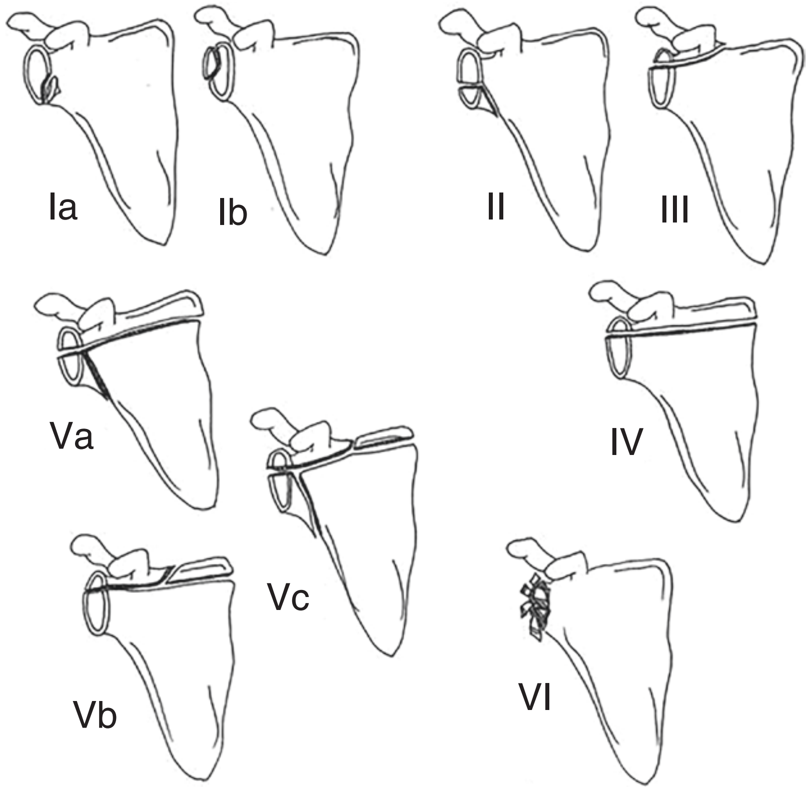

Fig. 28.2 Ideberg classification. (**Ia**) Anterior rim fracture. (**Ib**) Posterior rim fracture. (**II**) Fracture through glenoid exiting scapula laterally. (**III**) Fracture through glenoid exiting scapula superiorly. (**IV**) Fracture through glenoid exiting scapula medially. (**Va**) Combination of types II and IV. (**Vb**) Combination of types III and IV. (**Vc**) Combination of types II, III, and IV. (**VI**) Severe comminution

28.1.2 Extra-Articular Neck Fracture

Glenoid neck fractures are extra-articular, but the mechanisms are similar to that of intra-articular glenoid fractures, most commonly involving humeral head impact on the glenoid after direct lateral impact or a FOOSH injury. They can be classified into two main categories: Type I fractures, nondisplaced which respond to nonsurgical treatment, generally treated symptomatically with early range-of-motion exercises. Type II injuries involve greater than 1 cm of translational fragment displacement or more than 40° of angular displacement and most often require surgical repair. Anatomic neck fractures are inherently unstable and require surgical fixation. Surgical neck fractures can be unstable when they are associated with a clavicular fracture or with coracoclavicular and coracoacromial ligament disruption. This situation denominated by “floating shoulder” compels surgical repair. Internal fixation of the clavicular fracture generally results in adequate stabilization for healing of the glenoid fracture.

28.1.3 Scapular Body Fracture

Approximately 50% of scapular fractures involve the scapular body. The mechanisms include direct impact onto the scapula and sudden muscular contraction. These fractures respond well to conservative management and are usually treated nonsurgically in the acute phase. Operative fixation is rarely indicated, with non-operative measures generally effective. Open reduction may be considered when neurovascular compromise is present and exploration is required. Nonunion or malunion is uncommon but may require delayed surgical fixation if symptomatic, particularly with fragment displacement of greater than 10 mm or if impingement symptoms are present.

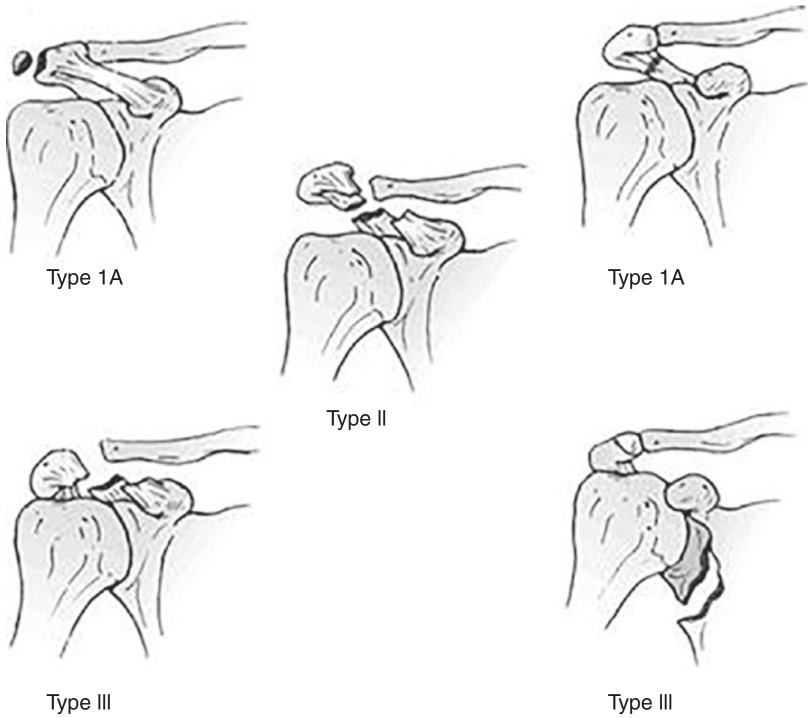

Fig. 28.3 Kuhn classification
Type I acromion fractures are nondisplaced and include Type IA (avulsion) and Type IB (complete fracture)
Type II fractures are displaced laterally, superiorly, or anteriorly, but they do not reduce the subacromial space
Type III fractures cause a reduction in subacromial space (Modified from Kuhn et al. [7])

28.1.4 Acromion Fracture

Fractures of the acromion are very rare and most often occur due to a lateral impact, a direct strike to the top of the shoulder, or, rarely, impact after superior humeral subluxation. They are classified with the Kuhn system into three types (Fig. 28.3).

Type I and minimally displaced type II fractures can be managed with immobilization. Surgical fixation is recommended for markedly displaced types II and III to reduce the acromioclavicular joint and prevent nonunion, malunion, impingement, or rotator cuff injury. Os acromiale must first be ruled out, as well as concomitant rotator cuff injuries. When displaced, acromion fractures lead to subacromial impingement; therefore, they need reduction and fixation by dorsal tension band wiring.

28.1.5 Coracoid Fracture

Coracoid fractures may appear in football injuries as injury mechanisms include a direct blow to the shoulder from a lateral impact, muscle avulsion, direct humeral head impact during anterior shoulder dislocation, and a variant of acromioclavicular joint separation. They are classified into two types with the Ogawa system. Type I fractures are proximal, and type II fractures are distal to the coracoclavicular ligament insertion. There is no clear consensus about the treatment of coracoid process fractures, but nondisplaced and minimally displaced fractures are most commonly type II and can be treated conservatively. Type I fractures are more likely to be markedly displaced. When associated with acromioclavicular separation, displaced acromial fracture, clavicular fracture, or glenoid fracture, these combinations commonly require surgical treatment. Complete third-degree acromioclavicular separation accompanied by a significantly displaced coracoid fracture is an indication for open reduction and internal fixation of both injuries.

28.2 Clavicle Fractures

Clavicular fractures represent approximately 2–4% of all fractures and 35–45% of shoulder girdle injuries [8]. The most common mechanism is fall onto lateral aspect of shoulder that generates compression of shoulder girdle, which translates into compression and distraction at clavicular shaft, resulting in clavicular fracture and tear of conoid ligament. Less common mechanisms are direct impact on the shaft and indirect FOOSH mechanisms. Patients usually present with splinting of the affected extremity, with the arm adducted across the chest and supported by the contralateral hand to unload the injured shoulder.

A careful neurovascular examination is necessary to assess the integrity of neural and vascular elements lying posterior to the clavicle. Most brachial plexus injuries are associated with proximal third clavicle fractures.

The proximal fracture end is usually prominent and may tent the skin. Assessment of skin integrity is essential to rule out open fracture. Up to 9% of patients with clavicle fractures have additional fractures, most commonly rib fractures.

Clavicular fractures are classified according to the Allman system. Group I involves the middle third of the clavicle and comprises approximately 80% of clavicle fractures. Group II (15%) involves the distal clavicle, and Group III (5%) involves the proximal clavicle.

28.2.1 Middle Third (Midshaft) Clavicle Fracture

More than 75–80% of clavicle fractures occur in the midshaft region. Displaced and shortened fractures of the mid-third of the clavicle are common in the young, athletic populations and are frequently high-energy sports injuries. It is this subgroup of patients with displaced and shortened midshaft fractures of the clavicle that often requires operative fixation.

In 2005, Zlowodzki et al. [9] found increasing age, fracture displacement, female gender, and fracture comminution to be associated with the development of nonunion and long-term sequelae after non-operative treatment. In 2006, Nowak et al. [10] found predictable risk factors including lack of osseous contact at fracture site, a transverse fracture, and increasing age that may cause complications in fracture healing and overall recovery and were considered to be indications for operative treatment. Studies of midshaft clavicle fractures with substantial shortening have reinforced these biomechanical findings by demonstrating higher patient satisfaction and improved functional outcomes after operative treatment. The traditional conservative protocol provides positive results in more than 90% of athletes treated with a figure-8 sling [11]. However, recent reports have discussed decreased union rates of displaced midshaft clavicular fractures treated non-operatively. Closed treatment may lead to significant deficits, whereas surgical management results in an earlier and more reliable return to full function [11, 12].

Displaced fractures of clavicle with shortening of 15 mm or more have better results with surgery. Operative fixation allows earlier rehabilitation with a high level of patient satisfaction with respect to shoulder function. Pain relief is faster and there is no need to use shoulder wraps. Rigid internal fixation may also allow patients to return to activities earlier. Reconstruction plates can be contoured best to the three-dimensional anatomy of the clavicle.

Operative management of clavicular fractures includes external fixation, intramedullary fixation, and osteosynthesis with plate and screws (Figs. 28.4 and 28.5).

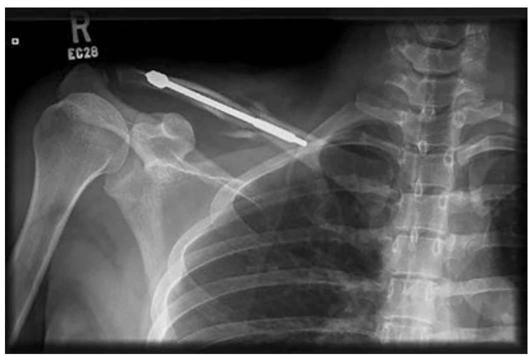

Fig. 28.4 Midshaft clavicle fracture with intramedullary fixation

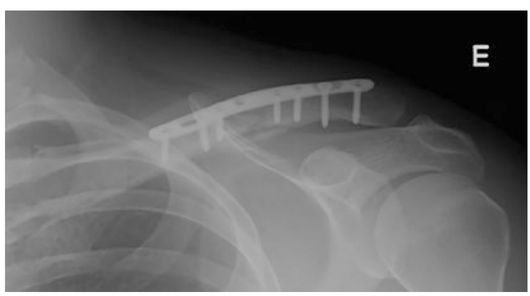

Fig. 28.5 Midshaft clavicle fracture fixed with plate and screws

With respect to displaced fractures, plating of 460 patients resulted in a nonunion rate of 2.2% compared with a nonunion rate of 15.1% in 159 patients treated non-operatively [13].

An athlete undergoing traditional treatment of a clavicular fracture would have been immobilized for 3–6 weeks before any range-of-motion exercises were started. However, in the past few years, more aggressive treatment protocols for clavicular fractures have become popular. Success rates of 94–100% with low rates of infections and complications have been reported with plate fixations of acute midshaft clavicular fractures [9]. Fixation with intramedullary nailing using titanium elastic nails has also evolved [13]. With surgical treatment and appropriate rehabilitation, athletes are able to return to competition at 6 weeks without compromising their health or safety [14, 15].

28.2.2 Distal Clavicle Fractures

The distal clavicle fractures (Group II of Allman) were divided into five subtypes according to the Neer classification modified by Craig [16]. Their classification is based on the location of the fracture in relation to the coracoclavicular ligament and their intactness (Fig. 28.6).

The Neer type I is a fracture lateral to the coracoclavicular ligament attachment, which has very minimal displacement. Type II is one which is medial to the ligament attachment. It is divided into IIA and IIB. In IIA both the conoid and the trapezoid ligaments are attached to the distal fragment, and in IIB the conoid is detached from the proximal fragment, while the trapezoid is attached to the distal fragment. Type III is one with intra-articular extension. Type IV occurs in

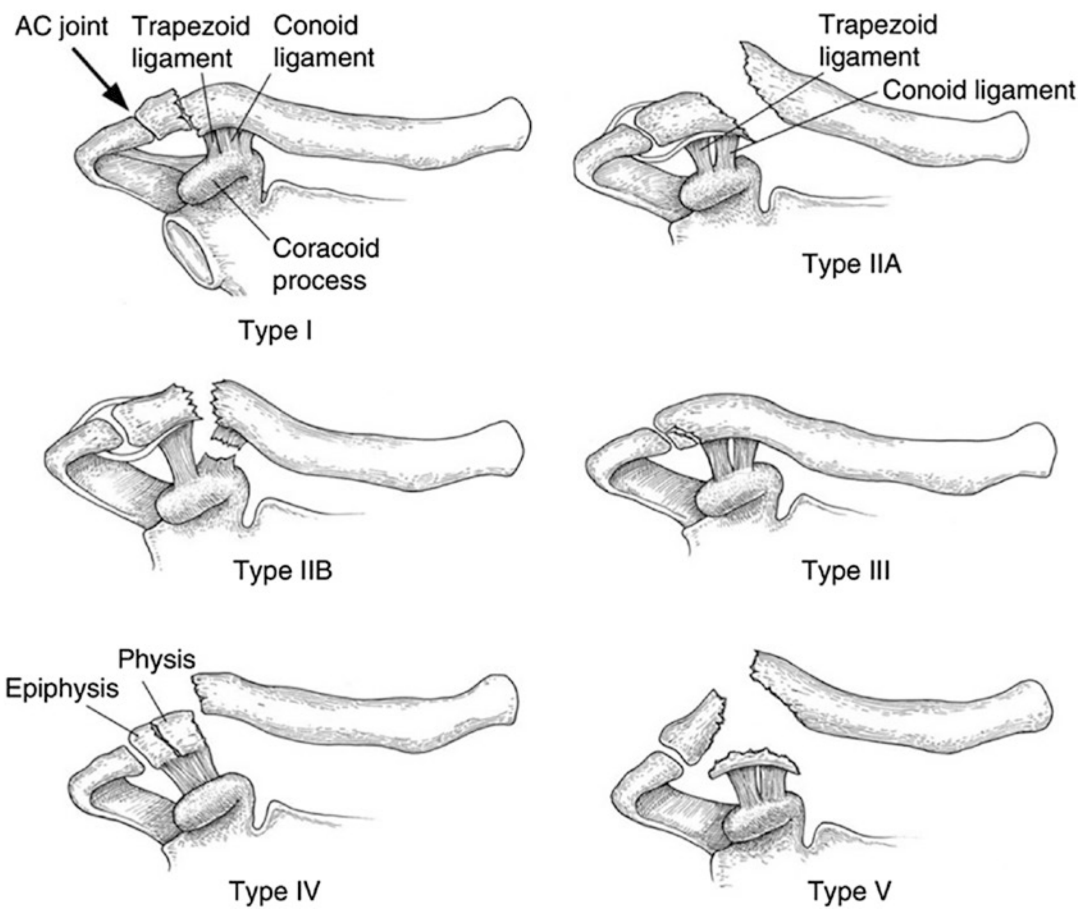

Fig. 28.6 Clavicle fractures Neer classification

children where a periosteal sleeve gets avulsed from the inferior cortex with the attached coraco-clavicular ligament, and the medial fragment gets displaced upwards. Type V is similar to type II which involves an avulsion leaving behind an inferior cortical fragment attached to the coraco-clavicular ligament. Types II and V are unstable, and there are many controversies about the best management.

The distal clavicle fractures accounts for 2.6–4% of the total adult fractures, more frequently seen in elderly females with osteoporotic bones than in young active adult. It can also happen as a football injury and may be remembered as differential diagnosis of acromioclavicular dislocations. Lateral end fracture constitutes 21–28% of all clavicle fractures, and of these 10–52% are displaced fractures. Till date there is no gold standard treatment recommendation for this injury. The unstable nature of these fractures makes them prone for nonunion and impeding normal shoulder function [17].

Treatment and outcome of the fracture of distal clavicle depends on displacement and injury to coracoclavicular ligament which makes the fracture unstable. Type 1 injuries are generally stable and not displaced and are managed conservatively with a sling to support the weight of the limb. Type 2 injuries are managed similarly but may lead to AC joint arthrosis which may deserve a distal clavicle resection. Type 4 is just a periosteal disruption in children, and bone fills the periosteal sleeve resulting in union and remodeling. The management of types 3 and 5 is the most controversial topic. Both being similar in instability and displacement can be considered together. Different treatment modalities are available for their management. Till date no gold standard technique has been described. The treatments available can be broadly divided into conservative management or rigid fixation such as osteosynthesis with locking plate (Fig. 28.7), hook plate fixation, fixation with a distal radius locking plate, coracoclavicular screws, or Knowles pin fixation. In addition, other treatment modalities are simple K-wire fixation, tension band wiring, suture anchors, vicryl tape, or Dacron arterial graft for coracoclavicular ligament reconstruction.

Fig. 28.7 Distal clavicle fixation with locking plate and suture anchors for coracoclavicular ligament reconstruction

28.2.3 Medial Clavicle Fractures

Fractures of the medial third of the clavicle are rare and constitute only 2–4% of all clavicle fractures [18]. These fractures have traditionally been treated non- operatively, even when they are significantly displaced with intervention classically being reserved for open fractures or fractures with neurovascular compromise [19].

However, non-operative treatment of these fractures can lead to poor functional outcomes and symptomatic, painful nonunions. Some studies reported an overall nonunion rate approaching 15%, and others stated that up to half of patients are symptomatic a year after injury [20]. Displaced fractures of the medial clavicle are uncommon. A fracture is considered to be displaced when displacement is more than 10 mm. Some authors have advocated non-operative treatment for these fractures; however, many case reports described complications when these fractures had been treated conservatively or missed [20]. When needed, the surgical treatment has demonstrated good results and full return to normal activities and sports. These goals are achieved after bone union which usually takes from 6 weeks to 4 months [21]. Oe et al. reported excellent functional outcomes for ten patients who underwent operative fixation of a displaced, periarticular medial-end clavicle fracture [22].

28.3 Proximal Humerus Fractures

Proximal humerus fractures are the seventh most frequent fracture in adults and the third in patients over 65 following wrist and femoral neck fractures. Approximately 5% of all fractures are fractures of the proximal humerus [23]. The mechanisms of these fractures can be classified as direct or indirect. The high impact during the football games leads to a higher proportion of direct fractures involving a direct impact along the shaft of the humerus in a traditionally high-energy non-axial force vector.

Although around 80% of the fractures may be treated conservatively, we have to consider the high demand and need of early return when treating football athletes. When surgical therapy is considered, early intervention can minimize the development of functional deficits, though the decision for surgical repair is also based on imaging findings, patient age, bone quality, rotator cuff status, fracture severity, and premorbid health [23].

The Neer classification remains the most commonly used system [24] and is based on six groups and four main fracture segments comprising the head, greater tuberosity, lesser tuberosity, and shaft (Fig. 28.8).

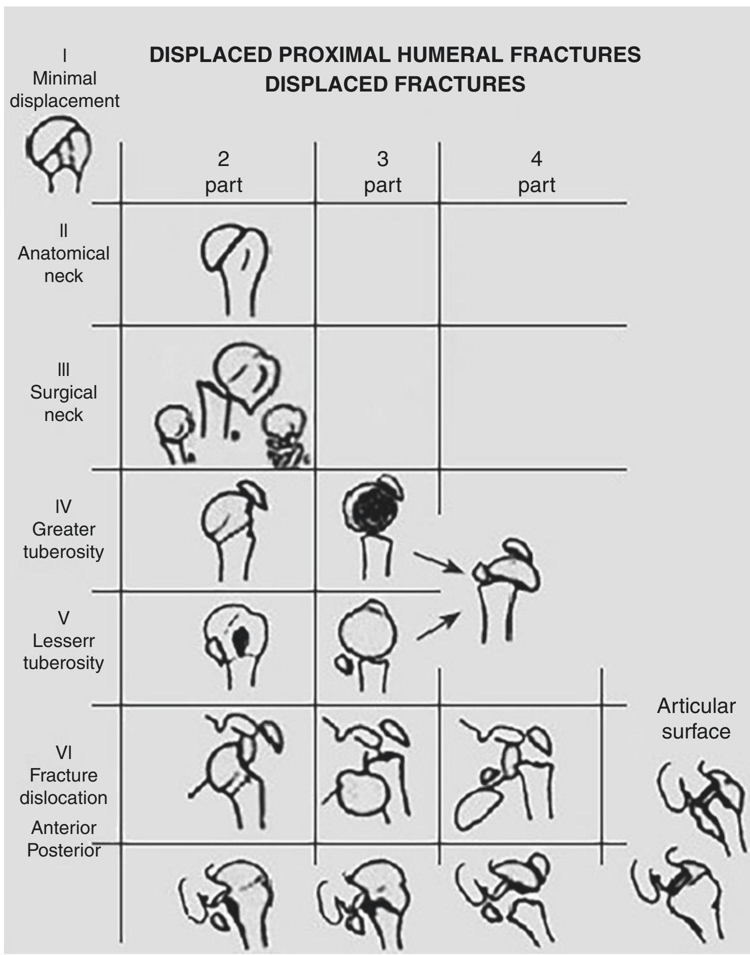

Fig. 28.8 Neer classification

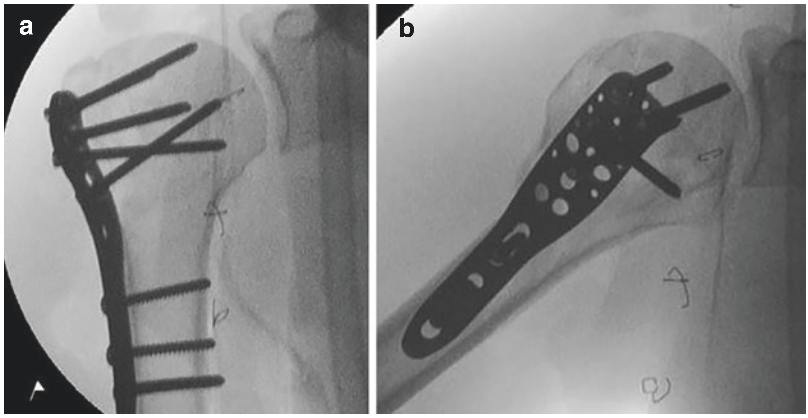

Fig. 28.9 Proximal humeral fixation with locking plate (**a**) Anteroposterior view (**b**) Anteroposterior view with internal rotation

Displacement is defined as more than 1 cm of translation or 45% of angulation. Group I includes all fracture configurations with minimum displacement and is treated conservatively. Group II includes two-part fractures of the anatomical neck with articular-segment displacement. Two-part fractures involving the surgical neck and lesser tuberosity can be treated conservatively if displaced less than 66% but are often best treated surgically. Treatment of two-part greater tuberosity fractures is often more aggressive, and surgery is usually recommended for fragment displacement greater than 3 mm in active younger patients, athletes, and people who engage in routine overhead activity. Group III comprises three types of displaced two-part surgical neck fractures with shaft displacement. Group IV consists of two- or three-part fractures with greater tuberosity displacement. Group V includes two- or three-part fractures with lesser tuberosity displacement. Groups IV and V merge in the four-part fracture where both tuberosities are displaced in addition to the head and shaft. Group VI comprises true fracture-dislocation of two-, three-, or four-part fractures with ligamentous injury and is subdivided into anterior and posterior dislocations of the glenohumeral joint and partial dislocations of the humeral head with articular surface fractures.

Conservative treatment generally consists of analgesia and a period of immobilization in a sling, followed by rehabilitation and physiotherapy. Complications encountered with closed treatment include malunion, subacromial impingement, avascular necrosis, shoulder pain, and stiffness secondary to osteoarthritis and rotator cuff deficiency. Most conservatively treated fractures will progress to full union with an estimated risk of nonunion between 1.1% and 10%.

The Neer three- and four-part fracture configurations are associated with less optimal results than one- or two-part fractures and fortunately are less common in younger patients. Seventy percent of all three- and four-part fractures are seen in patients aged over 60 years and 50% in patients aged over 70 years. With regards to the athletes, these fractures are best treated with open reduction and internal fixation (Fig. 28.9).

Operative interventions for the management of proximal humerus fractures may be generally classified into reconstructive procedures and prosthetic replacements. In high-demand young patients, reconstruction followed by close monitoring should be the first option. In the event of failure, early conversion to hemiarthroplasty remains a valuable alternative. Intraoperatively, the surgeon may find fractures that are not feasible for internal fixation, and they need to be converted to hemiarthroplasty. An adequate preoperative planning is necessary to be prepared for these demanding scenarios [25].

28.4 Humeral Shaft Fracture

Humeral shaft fractures account for about 5% of all fractures and are the third most common type of long bone fracture. They almost exclusively occur in young people following a high-energy trauma or older people following low-energy trauma. Many of these fractures are still being treated conservatively using functional (Sarmiento) bracing or a hanging arm cast. When these fractures are treated nonsurgically, union is obtained in an average of 10 weeks, making the humerus a well-suited bone for conservative treatment. This extended time usually is considered too long for athletes and young active people. Surgery allows them to quickly return to their activities. The goal of surgical treatment is to obtain anatomical reduction, while providing stability that allows for early mobilization of adjacent joints. It has its place in multi-fracture patients, open fractures, failed conservative treatment, and obese patients or those who refuse to comply with the inconveniences of conservative treatment with a hanging arm cast for 6 weeks, while accepting the risk associated with surgery (nonunion, secondary radial nerve palsy).

Surgical approaches to the humeral shaft include:

- Anterolateral approach: preferred for proximal third humeral shaft fractures. Radial nerve is identified in the interval between the brachialis and brachioradialis and traced proximally. This can be extended proximally to the shoulder or distally to the elbow
- Anterior approach: muscular interval between the biceps and brachialis muscles
- Posterior approach: provides excellent exposure to most of the humerus but cannot be extended proximally to the shoulder, muscular interval between the lateral and long heads of the triceps

When the surgical treatment is indicated, fixation can be obtained with a plate, intramedullary nailing, or an external fixator. The average nonunion rate in published studies was 4.4% for conservative treatment, 2.8% for plating, 6.3% for bundle nailing, 5.9% for locked IM nails, and 3.5% for external fixation [26].

- Plate and screw fixation of the fracture results in union in 11–19 weeks. This is associated with the best functional results. It allows direct fracture reduction and stable fixation of the humeral shaft without violation of the rotator cuff. A 4.5-mm dynamic compression plate with fixation of eight to ten cortices proximal and distal to the fracture is used. Lag interfragmentary compression screws should be utilized wherever possible. One should preserve soft tissue attachments to butterfly fragments
- Anterograde or retrograde locked intramedullary nailing requires knowledge of nailing techniques and regional anatomy to avoid the complications associated with the technique. Union is obtained in 10–15 weeks. It is preferably indicated for segmental fractures in which plate placement would require considerable soft tissue dissection, humerus fractures in extremely osteopenic bone, and pathologic humerus fractures. Antegrade humeral nailing is associated with a high incidence of postoperative shoulder pain (Fig. 28.10)

Fig. 28.10 Humeral shaft fixation (A) anterograde intramedullary interlocked nailing

– External fixation: indicated for infected nonunions, burn patients with fractures, or open fractures with extensive soft tissue loss. Complications include pin tract infection, neurovascular injury, and nonunion

Conclusion

The treatment of fractures in athletes needs a comprehensive approach. The first step is pain control, followed by the correct treatment option and lastly the recovery of motion, strength, and neuromuscular control. Sport-specific functional rehabilitation is very important and has to be tailored to each athlete. Special attention should be given on neuromuscular control of the kinetic chain, starting from core stability and progressing from the proximal to the distal segment. The kinetic chain as the main power generator for the upper limb must be recovered. The last phase and one of the most important is the on-field rehabilitation to give the footballer full skill control and self-confidence in playing. The complete process of functional recovery including surgery and rehabilitation takes the injured players 2–6 months out of the game depending on the severity of the lesion and individual factors.

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