Humerus

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Key Points

- Proximal humerus fractures and humeral shaft fractures occur most frequently in younger patients with high-energy trauma or elderly patients with low energy mechanisms.
- Fractures of the humerus are typically diagnosed clinically with deformity, tenderness, and ecchymosis at the site of injury.
- Plain radiographs will be able to detect the majority of humerus fractures, although CT may be useful for intra-articular fractures.
- The majority of humerus fractures will heal without surgical intervention.
- Return to sport is dictated by clinical and radiographic evidence of fracture healing**.**

Introduction

Injuries to the upper arm in sports can range from minor contusions to limb-threatening fractures in severe instances. Soft tissue injuries about the humerus can include contusions, muscle strains, tendinitis or tendon ruptures, and joint instability. Specifically in the shoulder, rotator cuff injuries and glenohumeral and acromioclavicular instability injuries are common in sports and may result in acute and chronic dysfunction.

Fractures in the humerus are relatively rare in sports as a significant amount of energy is required to cause a humerus fracture in a young and healthy individual. Certain sports that are particularly prone to humerus fractures include skiing, snowboarding, and cycling. Additionally, elderly individuals are at an increased risk of humerus fractures as lower energy falls may result in fracture due to decreased bone strength. This chapter will primarily focus on the epidemiology, presentation, diagnosis, and treatment for fractures of the proximal humerus and humeral shaft. Management of proximal and mid-shaft humerus fracture is summarized in Table 15.1.

Relevant Anatomy

The proximal humerus osteology forms from three separate ossification centers: the articular epiphysis, the greater tuberosity, and the lesser tuberosity. The ossification centers fuse together in early childhood and subsequently fuse to the humeral metaphysis between age 20 and 23 years. They account for important bony structures in the proximal humerus and are important in understanding the subtle differences in the types of proximal humerus fractures.

The greater tuberosity serves as the insertion point for supraspinatus, infraspinatus, and teres minor muscles, while the subscapularis attaches to the lesser tuberosity. The junction between the articular humeral head and the tuberosities is the anatomic neck, while the junction between the tuberosities and the humeral shaft becomes the surgical neck in the adult humerus (Fig. 15.1). The long head of the biceps brachii muscle runs in the intertubercular sulcus between the greater and lesser tuberosities. The pectoralis major, latissimus dorsi, and teres major tendons also insert in the

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M. Khodaee et al. (eds.), *Sports-related Fractures, Dislocations and Trauma*, https://doi.org/10.1007/978-3-030-36790-9_15

Table 15.1 Management guidelines for humerus fractures

	Proximal		Mid-shaft	
Fracture category	adults	Pediatrics	adults	Pediatrics
Initial immobilization	Sling	Sling or hanging arm cast	Coaptation splint	Coaptation splint
Follow up	1 week	1 week	1 week	1 week
Long-term immobilization type	Sling, nothing	Sling, nothing	Sarmiento brace	Sarmiento brace, long arm cast
Length of immobilization	2–4 weeks	2–4 weeks	6 weeks	4 weeks
Indications for referral to orthopedics	Displaced fractures Fracture-dislocations Open fracture Nerve or vascular injury	Displaced fractures Intraarticular fractures Fracture-dislocations Open fracture Nerve or vascular injury	Displaced fractures Open fracture Nerve or vascular injury Ipsilateral forearm fracture	Displaced fractures Open fracture Nerve or vascular injury Psilateral forearm fracture
Healing time	6–12 weeks	6–12 weeks	6–12 weeks	6–12 weeks
Return to sports	>3 months	>2 months	>3 months	>2 months

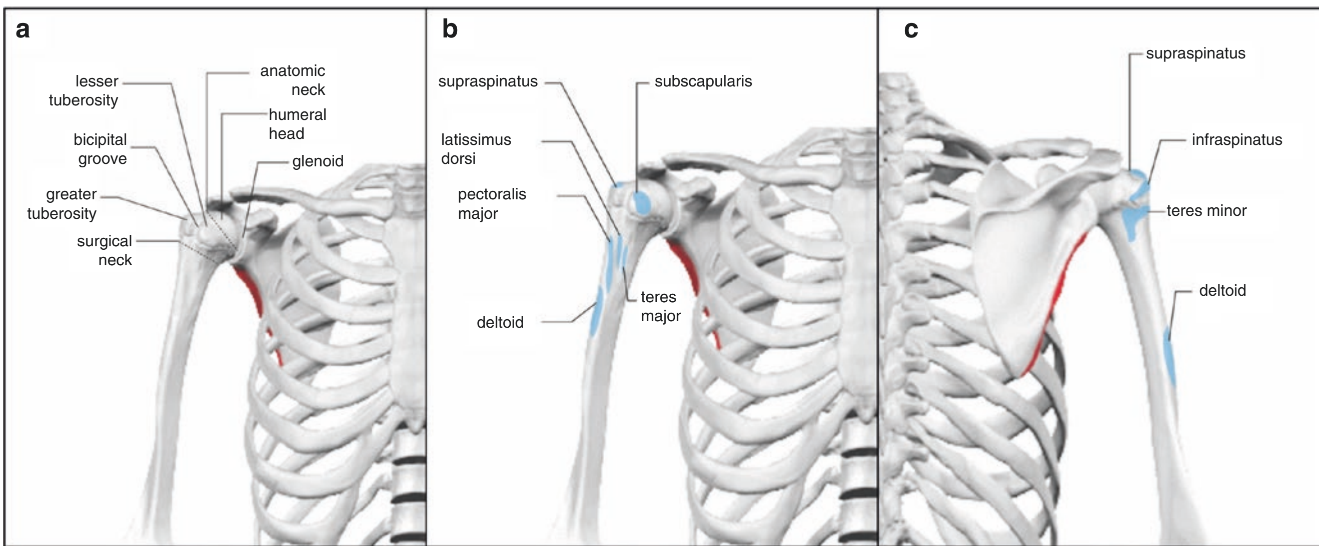

Fig. 15.1 Illustration highlighting the osteology (**a**) and pertinent tendinous insertions of the proximal humerus (**b**, **c**)

intertubercular sulcus in that order, respectively, from medial to lateral (Fig. 15.1).

The average humeral neck-shaft angle is 130°, and the humeral head is typically retroverted in comparison to the humeral shaft by 18°–30° [1]. The blood supply to the humeral head comes primarily from the anterior and posterior circumflex humeral arteries [2].

The mid-shaft of the humerus comprises an area from the surgical neck proximally to the supracondylar ridge near the elbow. The diaphysis of the humerus receives its blood supply from the axillary and brachial arteries. The radial nerve travels along the posterior mid-shaft in the spiral groove, then emerges anteriorly to cross the elbow. It supplies the innervation to the muscles of the posterior compartment of the arm. The deltoid attaches mid-diaphysis at the deltoid tubercle, while the pectoralis major attaches more proximally. The long head of the biceps brachii travels proximally in the bicipital grove.

Proximal Humerus Fractures

Mechanism of Injury in Sports

Proximal humerus fractures in younger patients are typically a result of high-energy trauma such as motor vehicle accidents or falls from height. An isolated proximal humerus fracture in a young and healthy patient is rare, obligating practitioners to perform a thorough examination of the involved extremity as well as the rest of the body. Conversely, proximal humerus fractures in the elderly population normally result after lower energy mechanisms such as a fall from standing. A proximal humerus fracture in an elderly individual is considered a fragility fracture, and an appropriate work up for osteoporosis should be performed [3].

In sports, proximal humerus fractures are rare overall. The most common injury mechanism is still from a fall onto an outstretched hand (FOOSH), but this is typically only seen in sports with particularly high energy associated with the fall such as in skiing, snowboarding, and cycling. While overall snowboarders sustain more humerus fractures than skiers, skiers proportionally are more at risk for proximal humerus fractures, while snowboarders sustain more distal humerus fractures [4].

Epidemiology

Fractures of the proximal humerus are common injuries, making up roughly 5% of all fractures [5]. Proximal humerus fractures occur in a bimodal type distribution. There is a small peak of proximal humerus fractures in the pediatric and young adult population, typically seen in higher energy trauma. A much larger peak incidence is seen in the elderly population, especially over age 70. Proximal humerus fractures affect females two to three times more frequently than males, and the average age of a patient with a proximal humerus fracture is 71 [6]. A national survey of emergency room visits estimated 370,000 total humerus fractures in 2008, 184,300 of which involved the proximal humerus. This number is expected to grow to 275,000 proximal humerus fractures by 2030 due to a growing elderly population [7]. Proximal humerus fractures are the third most common fracture in elderly patients behind hip and distal radius fractures [8]. The overall incidence of proximal humerus fractures in sports is not well defined in the literature; however, in skiers roughly 14% of all shoulder injuries are proximal humerus fractures [4].

Fracture Calcification

Several different classification systems exist for proximal humerus fractures. The AO/OTA classification for proximal humerus fractures groups them into unifocal extra-articular, bifocal extra-articular, and articular (Fig. 15.2) [9, 10]. A more commonly used classification is the Neer classification of proximal humerus fractures. This classification system groups fractures by the number of displaced parts as defined by angulation greater than 45° or displacement greater than 1 cm or 0.5 cm for the greater tuberosity (Fig. 15.3) [11]. The Neer classification system has moderate inter-observer reliability but has been shown to have superior reliability compared to the AO classification [12]. Extra caution is given to greater tuberosity fractures as they are prone to further displacement and poor functional results if displaced greater than 0.5 cm [13]. Fractures may be through the anatomic neck, the surgical neck, the greater tuberosity, and/or the lesser tuberosity [11]. In fractures involving the tuberosities, pull from the supraspinatus, infraspinatus, and teres minor will tend to cause posterior and superior displacement of the

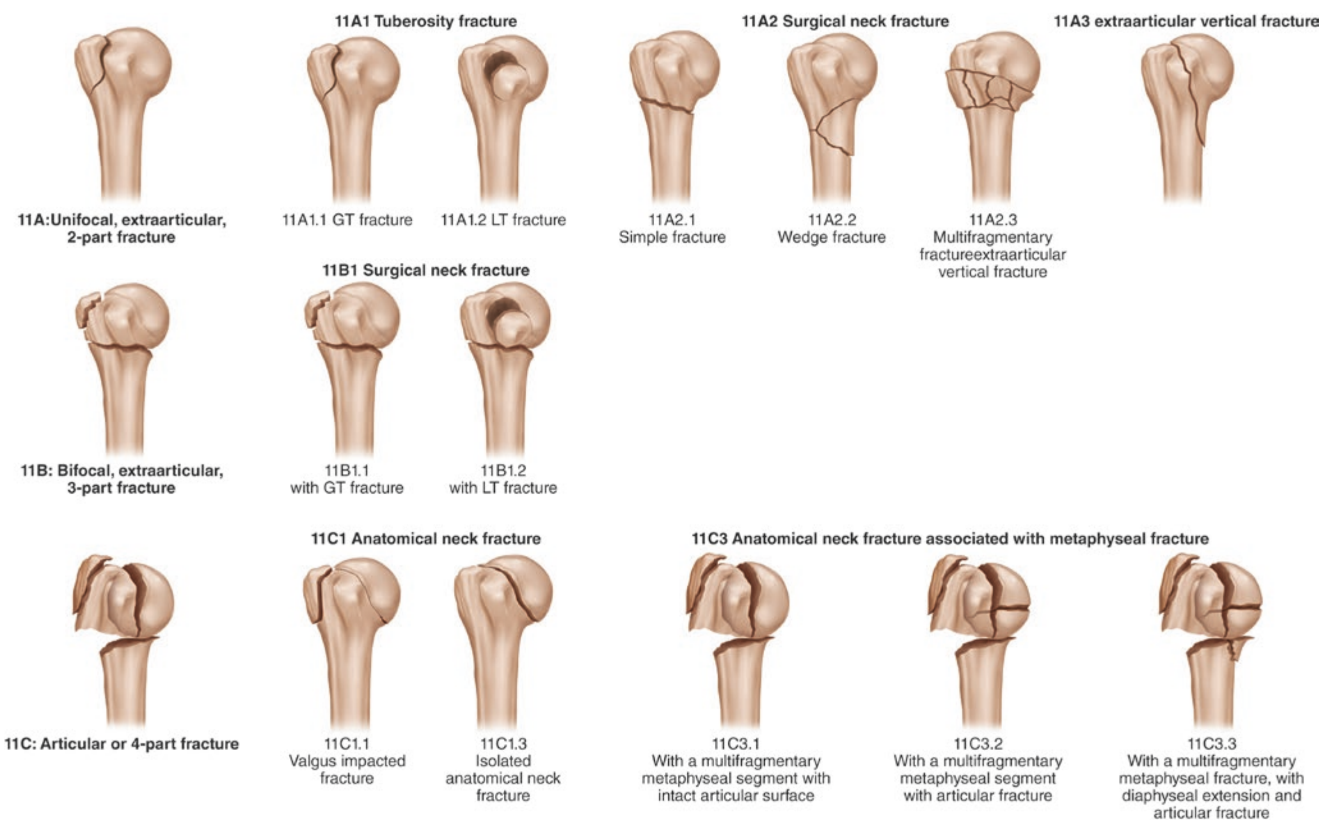

Fig. 15.2 Illustrative depiction of the AO/OTA (AO Foundation/Orthopaedic Trauma Association) classification system for proximal humerus fractures [9, 10]

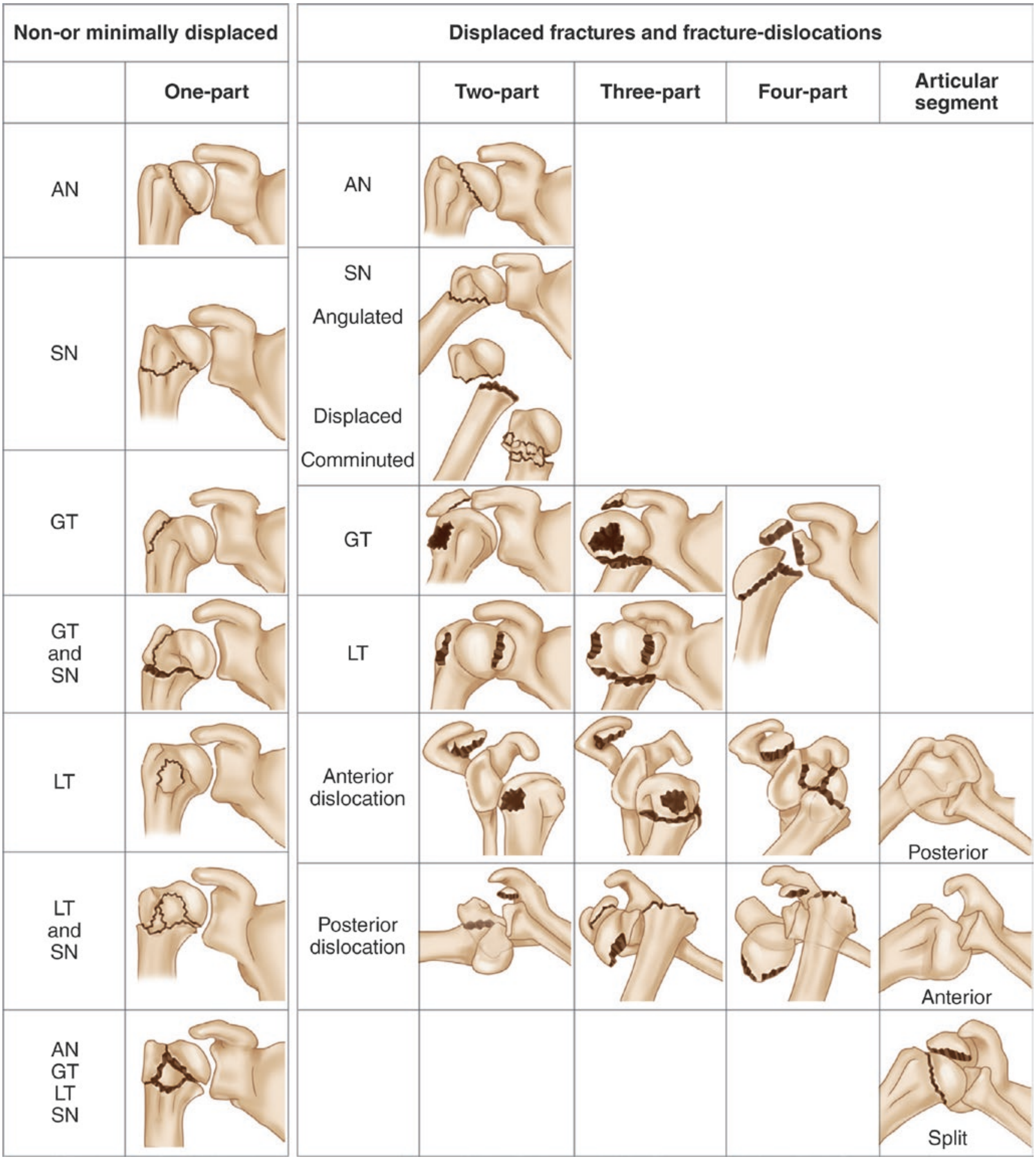

Fig. 15.3 Illustrative depiction of the Neer classification system for proximal humerus fractures [11]. AN, anatomical neck; SN, surgical neck; GT, greater tuberosity; LT, lower tuberosity

greater tuberosity fragment, while pull from the subscapularis will displace the lesser tuberosity fragment medially.

Fracture-dislocations of the proximal humerus must be treated with caution (Chap. 14). An attempted closed reduction of a GHJ dislocation with associated minimally displaced proximal humerus fracture may cause displacement of the fracture and necessitate surgical management. If the GHJ dislocation is unable to be reduced in a closed manner with gentle reduction maneuvers, urgent surgical management is recommended.

Clinical Presentation

On visual inspection of a patient with a proximal humerus fracture, one may note swelling and ecchymosis to the shoulder as well as in the distal extremity and chest due to settling of the hematoma. Some patients may present with an obvious deformity (Fig. 15.4), but most will not. A thorough neurovascular examination is crucial as proximal humerus fractures are associated with neurologic injury up to two third of the time [14]. The most commonly injured nerve is the axillary nerve followed by the suprascapular nerve [14]. The majority of neurologic injuries are transient and resolve in time.

Imaging

A specific series of plain radiographs is required for any patient in which a proximal humerus fracture is suspected. This includes an anteroposterior (AP) view of the GHJ (Grashey view), a scapular Y view, and an axillary view (Fig. 15.5). A true axillary view may be painful for patients, in which case a Velpeau modification is acceptable [15] (Fig. 15.6). Collectively these views allow for adequate visualization of the proximal humerus as well as the GHJ which is critical to assess for dislocation or subluxation of the GHJ. It is important to note that a patient may appear to have inferior subluxation of the humeral head which in fact is just a result of deltoid atony (Fig. 15.7). Additional views may include an AP view with the arm in internal or external rotation. In patients with a diagnosed proximal humerus fracture, full length anteroposterior and lateral radiographs of the humerus are also recommended.

Advanced cross-sectional imaging is not usually necessary in evaluation of proximal humerus fractures. CT is useful in evaluating shoulder fracture dislocations and associated glenoid fractures, and may also be helpful for better evaluation

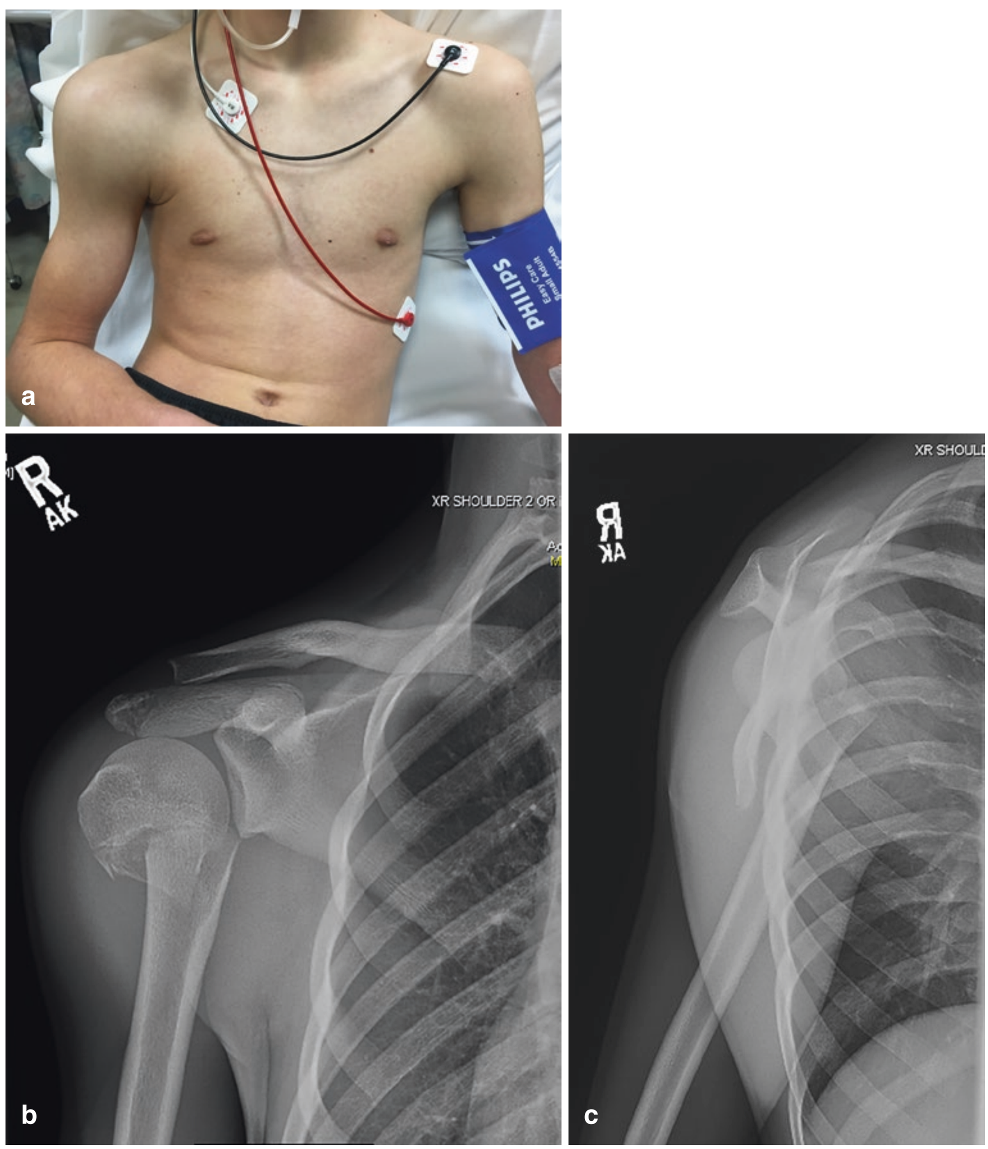

Fig. 15.4 A 15-year-old male who sustained a right Salter-Harris type II proximal humerus fracture after a fall while ski jumping. Clinical photograph demonstrates deformity (effusion due to hemarthrosis) (**a**) and associated AP (**b**) and scapular Y (**c**) view radiographs

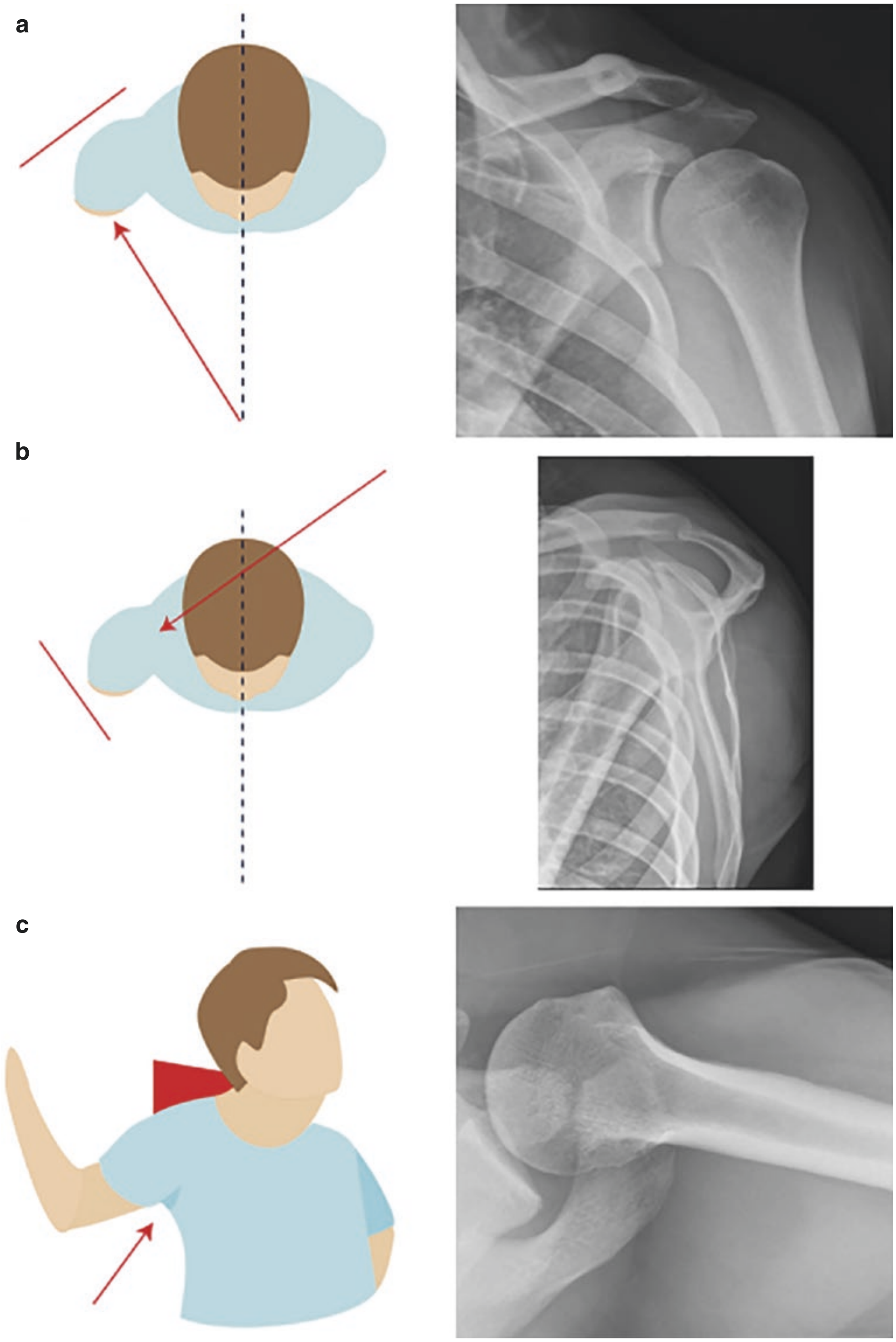

Fig. 15.5 Illustration and corresponding radiographs of the three standard shoulder radiographs for trauma (AP, Scapular Y, and axillary views)

of intra-articular fractures and fractures of the greater or lesser tuberosities (Fig. 15.8). CT scans in proximal humerus fractures have not been shown to improve fracture classification, but they may be helpful in pre-operative planning [16, 17]. MRI is rarely used in the setting of acute proximal humerus fractures, except in the setting of an occult fracture not visualized on plain radiographs or concern for concomitant rotator cuff tear.

Initial Management

When a player on the field is suspected to have a proximal humerus fracture, they must be immediately removed from play. Initial management should include a thorough neurologic and vascular examination. Any clothing must be removed so that the shoulder can be inspected for open wounds, ecchymoses, or deformity. The injured shoulder

Fig. 15.6 Photograph depicting proper positioning and technique for a Velpeau radiograph

Fig. 15.7 AP radiograph of a shoulder demonstrating inferior subluxation of the humeral head in the setting of a proximal humerus fracture due to deltoid atony

should be compared to the non-injured shoulder. Palpation of all bony aspects of the shoulder for tenderness or crepitus is important including the humerus, acromion, scapular spine, and clavicle. A range of motion examination should then be performed if the player is able to tolerate it. If suspicion for a proximal humerus fracture persists, the player must be removed for the remainder of the game and radiographs should be obtained urgently. In a clinical setting, the same principles apply for examination. The primary tool for diagnosing proximal humerus fractures is with plain radiographs; therefore, low threshold should exist for obtaining them urgently if a proximal humerus fracture is suspected.

A standard sling should be applied after evaluation to immobilize the shoulder to both protect the shoulder, and provide pain relief. This may be done prior to obtaining official radiographs. In the initial management phase, a standard sling is acceptable for immobilization. No type of splint or cast exists that can help immobilize a proximal humerus type of fracture.

Indications for Orthopedic Referral

There are several proximal humerus fracture patterns that should be referred to orthopedic surgery. The majority of proximal humerus fractures are treated nonsurgically; however, this decision is made on a case-by-case basis. Any displaced proximal humerus fractures warrant referral. We would also recommend referral for a younger patient with a nondisplaced greater tuberosity fracture as this fracture pattern is at high risk of displacement. Finally, patients with multiple injuries should be referred to orthopedic specialist as surgical fixation may allow for faster mobilization.

Surgical emergencies that must be referred to an orthopedic surgery provider or an emergency department immediately include open fractures, fractures with associated vascular compromise, and proximal humerus fracture-dislocations. These injuries must be addressed either emergently or at a minimum within 24 hours.

Follow-Up Care

As with many orthopedic injuries, a large variety of treatment options exist for proximal humerus fractures. These include nonsurgical treatments, percutaneous surgical treatments, operative fixation, and replacement options. Treatment strategy is determined by a variety of considerations including fracture location and displacement, concomitant injuries, and patient factors. A certain proximal

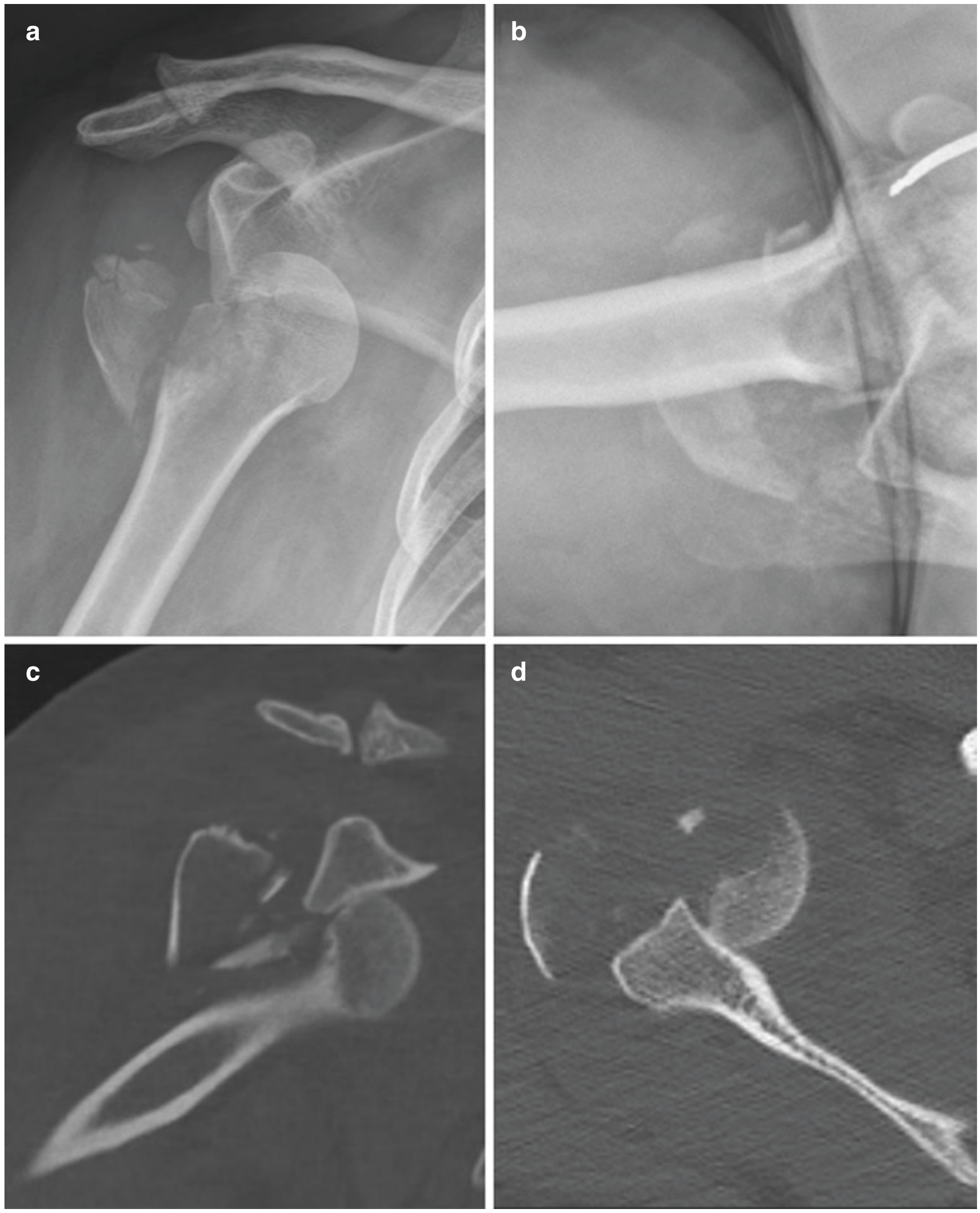

Fig. 15.8 AP and axillary plain radiographs (**a**), (**b**) of a proximal humeral fracture/dislocation with an associated greater tuberosity fracture. Coronal and axillary CT cuts (**c**), (**d**) demonstrate the degree of displacement of the fracture

humerus fracture in one patient may be treated different than a similar fracture in a different patient, and it is up to the treating practitioner to determine the best way to manage the patient as a whole.

Nonoperative Management

The majority of proximal humerus fractures are treated conservatively without surgery, with a recent survey of Medicare database estimated that 84% of all proximal humerus fractures are treated nonsurgically [18]. A significant amount of fracture displacement and angulation can be tolerated in proximal humerus fracture compared to fractures in other parts of the body. This is because the GHJ has more motion than any other joint in the human body, and malunions in this area will still allow for functionally acceptable range of motion.

Traditionally, one-part fractures based on the Neer classification are treated conservatively without surgical intervention. This includes fractures with less than 45° of angulation and 1 cm of displacement, except in greater tuberosity fracture where displacement must be less than 0.5 cm [11]. Other factors to consider are patient age, overall health status, coinciding injuries, and hand dominance. Recent studies have challenged this standard, however, showing that nonoperative management may have a role in displaced proximal humerus fractures as well [19]. The Proximal Fracture of the Humerus Evaluation by Randomization (PROHFER) trial was a multi-center randomized controlled trial that compared nonoperative to operative management in displaced surgical neck proximal humerus fractures [19]. This study found no significant difference in mortality rates, functional outcomes, or quality of life scores 2 and 5 years after the injury [19, 20]. A similar conclusion was drawn from a recent meta-analysis [21]. While this evidence cannot be generalized for all patients, it does suggest that conservative management may be acceptable in displaced surgical neck fractures. When specifically looking at younger patients with sport-related injuries, surgical fixation may be indicated more often as it allows athletes to mobilize the extremity more quickly. Additionally, athletes with high-energy mechanism injuries tend to have a higher incidence of greater tuberosity fractures which may trend towards surgical fixation.

A clear algorithm for nonsurgical treatment of proximal humerus fractures does not currently exist. Most providers immobilize patients for a short period of time, followed by a period of progressive increased motion under the guidance of physical therapy. Immobilization is typically in a standard commercially available arm sling. While this is a cost-effective option, some providers do advocate for a neutral rotation shoulder immobilizer to hold the proximal humerus in a more anatomic position during the healing process. This is particularly important in greater tuberosity fractures, as the greater tuberosity fragment is being displaced in a posterior and superior position, so holding the arm in a relatively internally rotated position may displace this fragment further (Fig. 15.9). Historically, patients have also been immobilized in a hanging arm cast or cuff and collar sling (Fig. 15.10), but these are frequently not well tolerated by patients and lead to worse long term outcomes compared to a regular sling [22]. However, there is no good evidence to support these additional slings.

While proximal humerus fractures were traditionally treated with prolonged immobilization, several studies have demonstrated that early mobilization results in improved functional and pain scores especially within the first 3 months post-injury [21, 23, 24]. These studies found that immediate mobilization within several days after the injury with a physical therapist was superior to immobilization for 3 weeks followed by therapy [21, 23, 24]. Most physical therapy protocols first entail a 2–4 weeks of directed passive range of motion and pendulum exercises. This followed by progressive active range of motion exercises for several weeks, and then strengthening exercises at a minimum of 6 weeks post-injury [23–27].

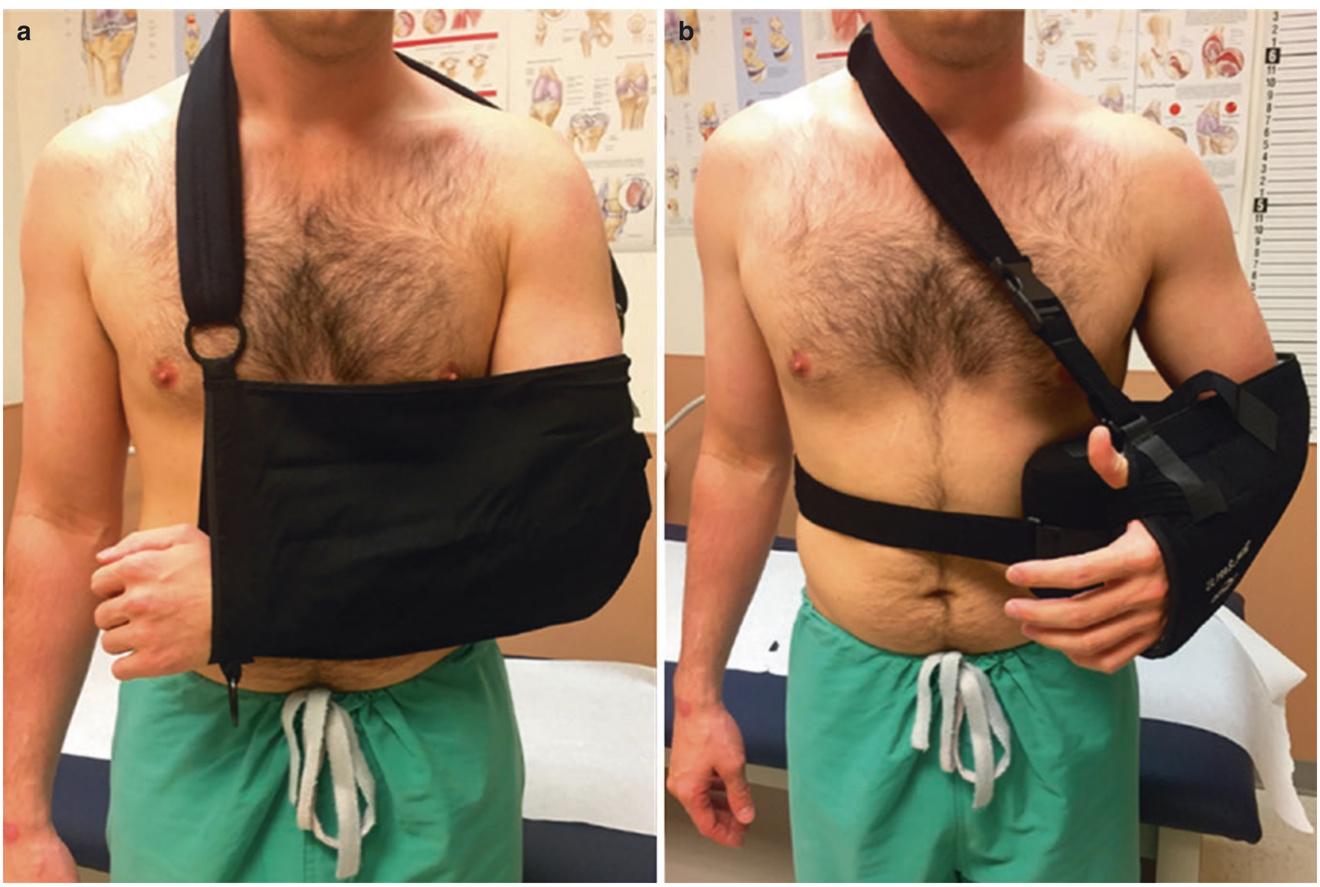

Fig. 15.9 An example of a standard sling (**a**), and a neutral rotation shoulder immobilizer (**b**)

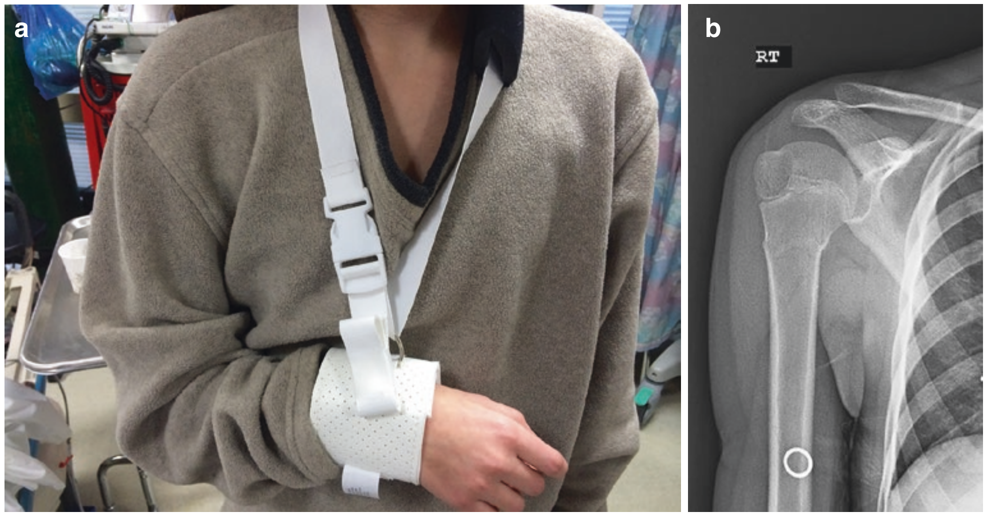

Fig. 15.10 A cuff and collar (**a**) immobilization in a 12-year-old female who sustained an extra-physeal proximal humerus fracture (**b**) during a snowboarding accident

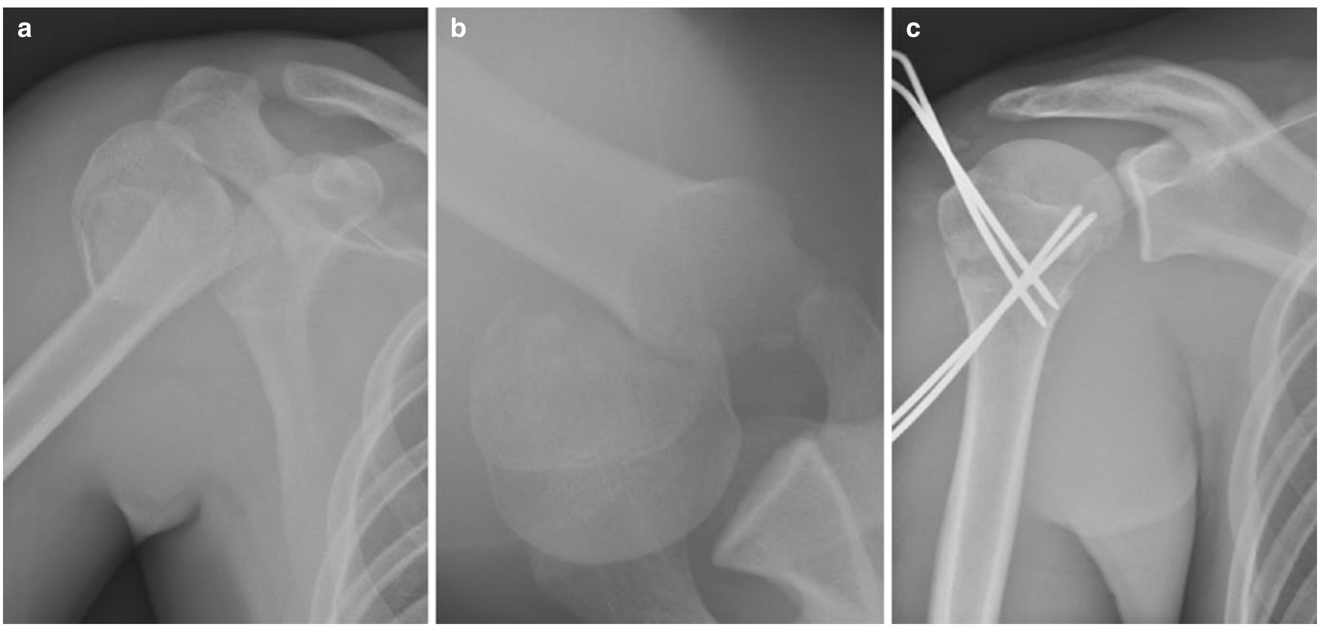

Fig. 15.11 Preoperative (**a**), (**b**) and postoperative (**c**) radiographs after closed reduction and percutaneous pinning of an unstable, completely displaced proximal humerus fracture in a 16-year-old male

When treating proximal humerus fractures nonsurgically, it is recommended to obtain radiographs at the following intervals: 1 week, 2 weeks, 6 weeks, 3 months, 6 months, and 1 year post-injury. If the injury is at particular high risk of displacement, then an additional radiograph 3 weeks after the injury may be indicated as well. We recommend clinical judgment for individualized follow up care and repeating radiography.

Operative Management

The two broad categories of surgical management are reduction with internal fixation and shoulder replacement. The methods of reduction with internal fixation may include closed reduction and percutaneous pinning (Fig. 15.11), intramedullary nailing, or open reduction and internal fixation with a proximal humerus locking plate (Fig. 15.12). Shoulder replacement type procedures are reserved for lower demand patients, or individuals with severely comminuted fractures (Fig. 15.13). With younger patients and sport-related injuries, the vast majority of cases are going to be with closed reduction and percutaneous pinning or open reduction and internal fixation as shoulder replacement surgeries are reserved for salvage cases or low-demand patients.

Return to Sports

Return to sport after operative or nonoperative management is similar. Patients must be clinically and radiographically healed prior to be released for play without restrictions. This means minimal tenderness at the fracture site, full and painless shoulder range of motion, and radiographic evidence of bony callus healing. This will typically be at minimum 3 months post-injury.

Complications

Short-term complications from proximal humerus fractures are typically related to any nerve or vascular injuries sustained. In closed injuries, most neurologic injuries do improve as they are from a reversible neuropraxic type event. Long-term complications from proximal humerus fractures include fracture nonunion or malunions, muscle weakness, and shoulder stiffness. Weakness and stiffness can typically be addressed with aggressive physical therapy. In patients undergoing surgical intervention, other risks include iatrogenic nerve, vascular, or muscle injury, infection, bleeding, and hardware failure.

Pediatric Proximal Humerus Fractures

Mechanism of Injury in Sports

Proximal humerus fractures in children usually result from a backward fall onto an outstretched arm or a direct fall onto the shoulder [28]. Fractures may also occur from direct trauma to the arm, non-accidental trauma or a pathologic fracture.

Epidemiology

Proximal humerus fractures in the pediatric population are relatively uncommon and account for less than 5% of all pediatric fractures. They are most often seen in adolescents and the most common type is a Salter-Harris type II fracture of the proximal humerus (Fig. 15.4) [29]. In younger children, fractures are more often seen in the metaphysis, which is rapidly growing and is thought to be relatively weak during rapid growth, making it more prone to injury.

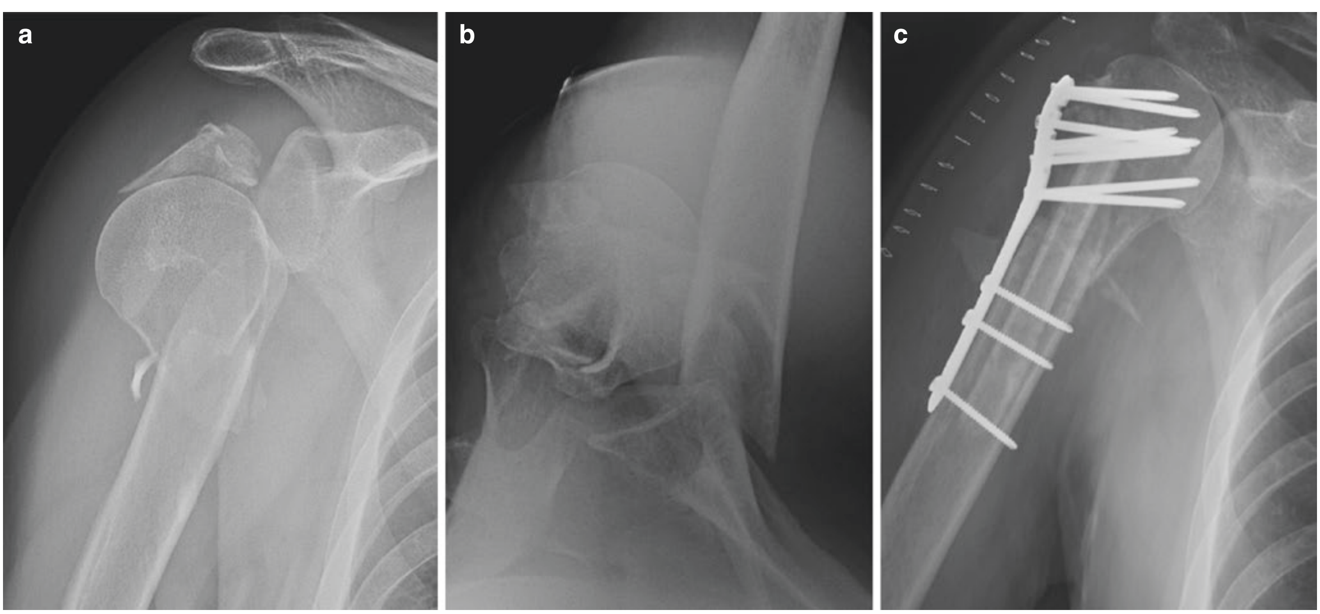

Fig. 15.12 Preoperative (**a**), (**b**) and postoperative (**c**) radiographs of a patient with a proximal humerus fracture undergoing open reduction and internal fixation with a proximal humerus plate

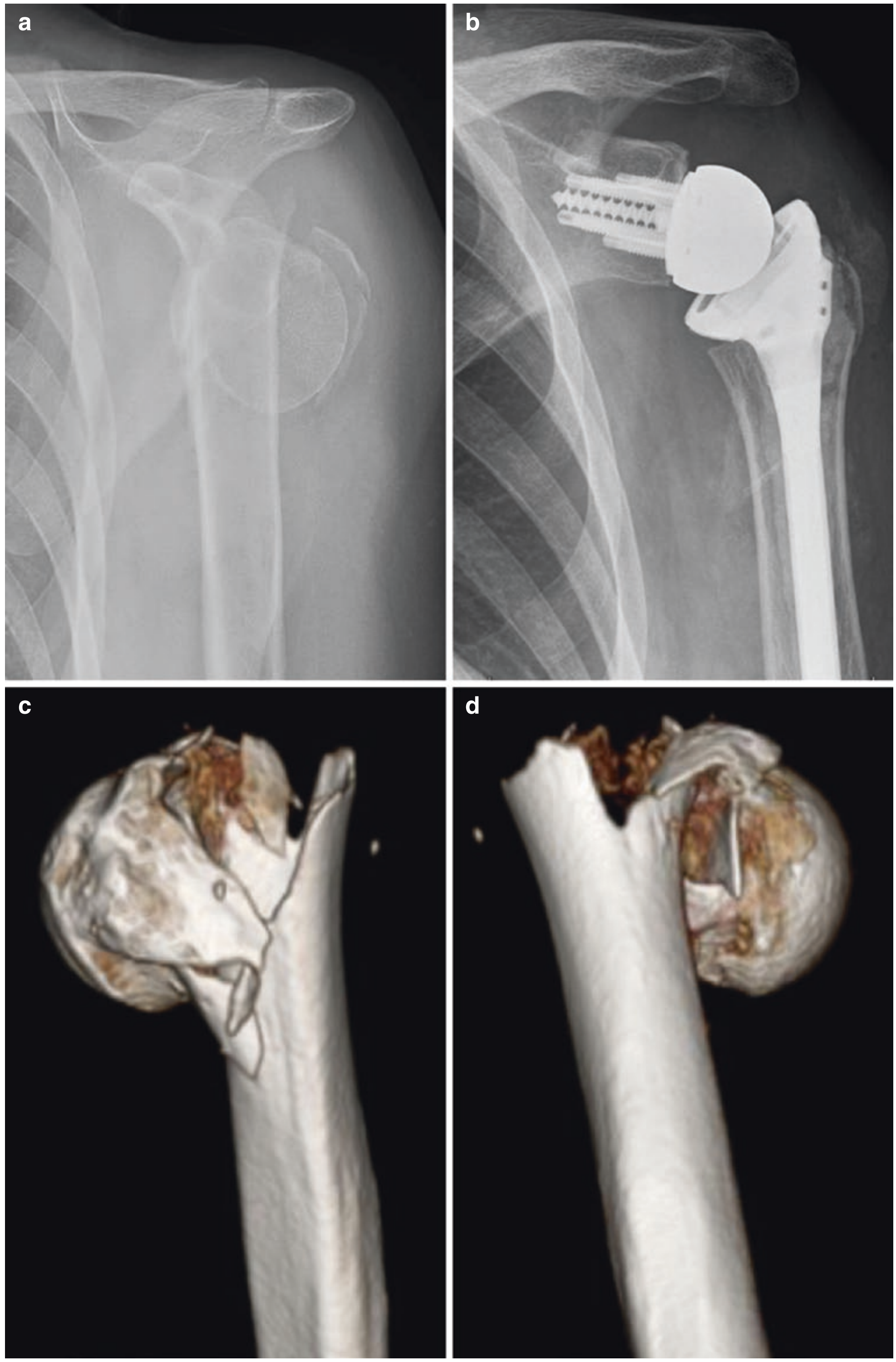

Fig. 15.13 Radiographs of a patient with a proximal humerus fracture (**a**) that was treated with a reverse shoulder arthroplasty (**b**). 3D CT demonstrates the extend of the fracture (**c**), (**d**)

Fracture Classifications

Specifically for pediatric proximal humerus fractures, the Neer-Horowitz Classification system groups fractures into nondisplaced (Type I), displaced less than 1/3 of shaft width (Type II), displaced 1/3 to 2/3 of shaft width (Type III), and displaced greater than 2/3 of shaft width (Type IV). Additionally, the Salter-Harris classification for physeal injuries may be applicable.

Clinical Presentation

The injured child may present with swelling, pain, and decreased motion of the injured arm. Diagnosis is made with plain radiographs.

Management

It is important to assess the neurovascular status of the arm distal to the injury and for any evidence of deformity of the arm. The injured arm should be placed in a sling until further radiographic assessment can be performed.

Most fractures heal well with sling immobilization. In children, healing is more rapid compared to adults and many children will have visible callus on imaging 2–3 weeks after the injury. Children are able to heal and remodel fractures with moderate displacement and angulation without the need for surgery [28].

Return to sports can be considered when the young athlete has no pain and tenderness on exam, full range of motion of the arm at the shoulder and elbow and evidence of healing on X-ray.

Indications for Orthopedic Referral

Emergent referral is necessary with any sign of neurovascular compromise, open fracture, or gross deformity. Proximal humerus fractures that require reduction changes dependent on patient age. If the patient is younger than 10 years, any angulation is typically acceptable as they will remodel significantly. Ages 10–13 years can tolerate up to 60° of angulation, while children over 13 years old can tolerate 45° of angulation [28]. Fractures outside of this range should be referred to an orthopedic surgeon as well as and displaced intra-articular fractures.

Complications

Complications after a humerus fracture in pediatrics are rare. If there is persistent angulation of the fracture after healing, arm function is still usually very good. If the fracture involved the growth plate, there could be premature closure of the injured physis. This could cause relative shortening of the injured arm compared to the contralateral side [28]. However, this may happen with Salter-Harris V.

Humeral Shaft Fractures

Mechanism of Injury in Sports

The mechanism of injury in humeral shaft fractures is similar to proximal humerus fractures as noted above. There is a relative trend toward humeral shaft fractures being associated with higher energy mechanisms that proximal humerus fractures as diaphyseal bone is stronger than metaphyseal bone. Stress fractures, although uncommon in the humerus, may occur with upper extremity dominant sports such as tennis, baseball, or swimming [30].

Epidemiology

Mid-shaft humerus fractures are less common than other types making up approximately 2% of all fractures. In children, they comprise fewer than 3% of all fracture types [31]. There is a bimodal distribution with peak incidences occurring in the third and seventh decades [32]. Trauma in males accounts for the first peak, while simple mechanical falls in females accounts for the second, representing changes in aging bone. Sports-related trauma accounted for 4.6% of all mid-shaft fractures with the predominant type being AO type A.

Fracture Classification

The AO/OTA classification system is often used to characterize humerus shaft fractures (Fig. 15.14) [9, 10]. The classification system is based on location of the fracture (proximal, mid-shaft, and distal), as well as the fracture pattern (simple patterns, wedge patterns, and comminuted patterns).

Fractures that occur at the midpoint of the diaphysis, below the attachment of the deltoid, tend to have an apex lateral angulation. This occurs as the deltoid pulls the proximal fragment laterally and the distal fragment moves medially. Fractures occurring above the deltoid attachment have a proximal segment that is pulled medially by the pectoralis muscle. The distal segment is pulled laterally by the deltoid. Mid-shaft fractures are often shortened as a result of muscle contraction by the deltoid, triceps, and biceps muscles.

Clinical Presentation

Athletes present with pain, swelling, and usually an obvious deformity to the humerus (Fig. 15.15). The fractured segment

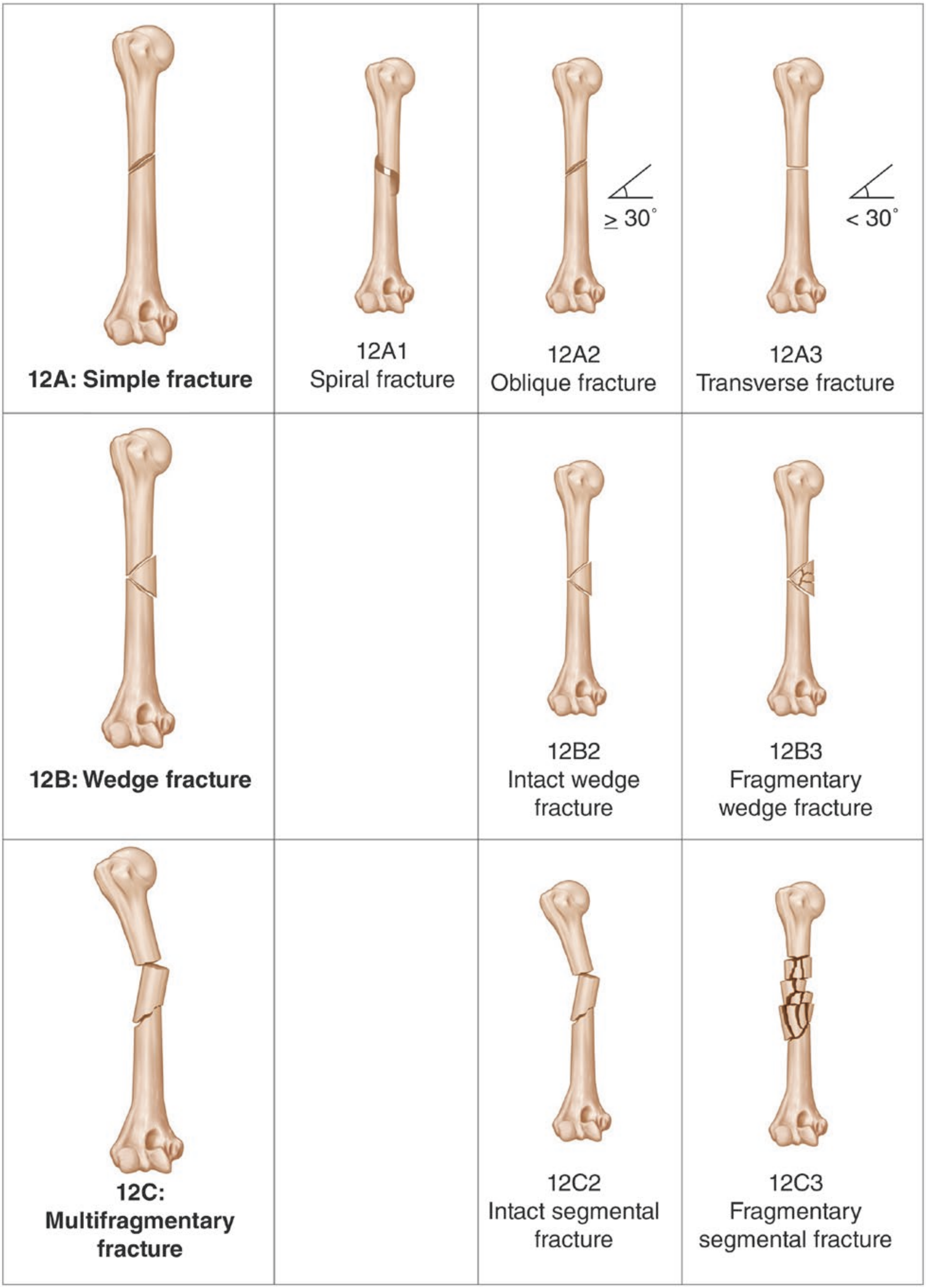

Fig. 15.14 Illustrative depiction of the AO/OTA (AO Foundation/Orthopaedic Trauma Association) classification for humeral diaphyseal segment fractures [9, 10]

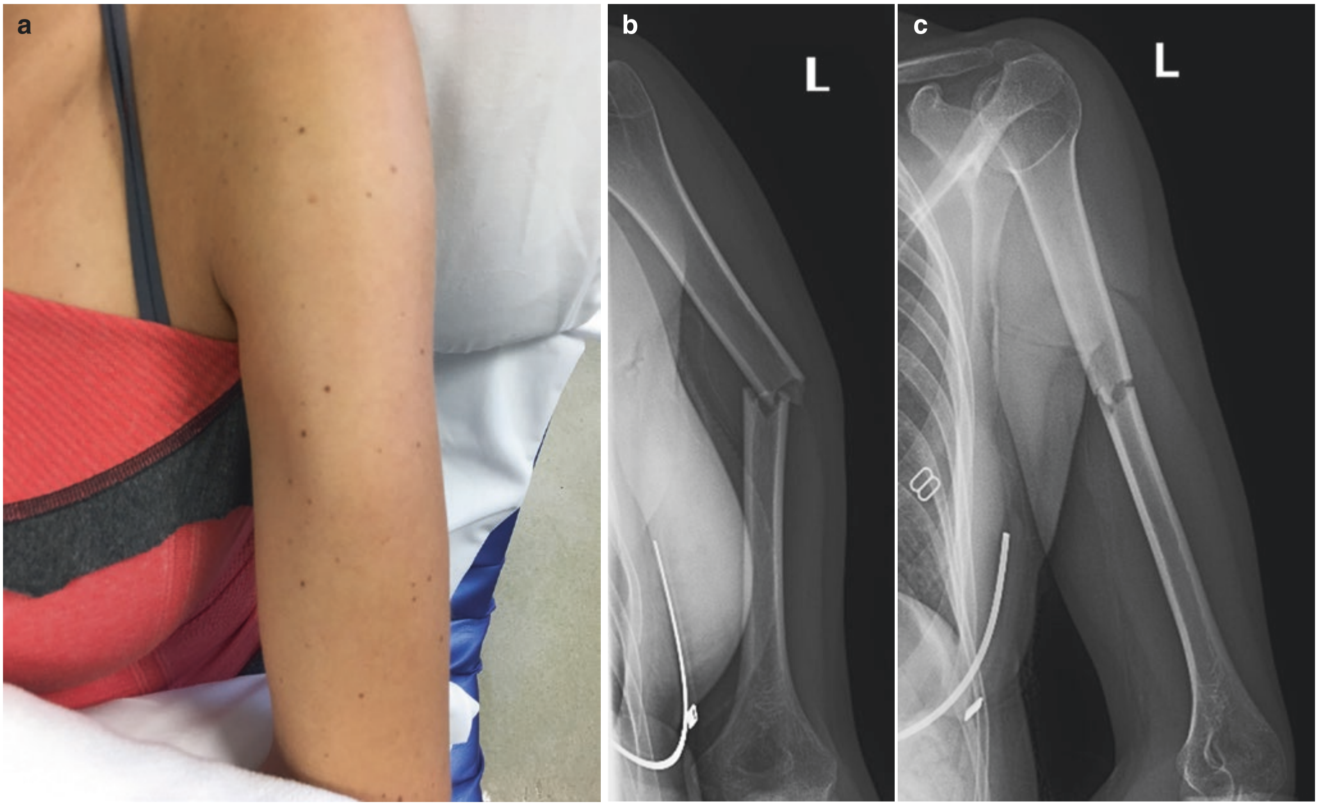

Fig. 15.15 Clinical (**a**) and radiograph (**b**, **c**) images of a 19 year-old female who sustained a humeral shaft fracture with deformity after a fall while skiing

will often be very mobile with crepitus upon palpation. Open fractures occur in less than 10% of cases but necessitate the need for emergent surgical consultation, antibiotics, and a proper dressing [33]. A thorough neurologic examination is essential. Damage to the radial nerve near the fracture site may cause wrist drop as the nerve innervates the common extensor musculature. Sensory examination may reveal decreased sensation in the first web space of the hand. Vascular injury is possible which may decrease the radial pulse at the wrist.

Imaging

Plain radiographs are essential for fracture characterization. Two orthogonal views are necessary and usually sufficient to fully describe the fracture (Fig. 15.16). Spiral and oblique fractures can sometimes be difficult to diagnose. The shoulder and elbow joints should be included in the views to access for extension of any injury [34].

CT scans and MRIs are usually not necessary unless a nerve or arterial injury is suspected.

Initial Management

The initial management on the playing field or in the office is the same as with proximal humerus fractures. Initial management includes relative immobilization with a sling and swathe, cuff and collar, or co-optation splint with sling (Fig. 15.17). Following initial management, the use of a functional brace (Fig. 15.18) has been shown to provide adequate immobilization with low rates of nonunion [35].

Indications for Orthopedic Referral

Emergent referral to an orthopedic surgeon is necessary for open fractures, fractures with associated neurologic or vascular injury, or fractures associated with compartment syndrome. These injuries should be sent directly to an emergency department for further evaluation for surgical intervention.

Nonurgent humeral shaft fractures that require referral to orthopedic surgery include fractures in unacceptable alignment, patients with multiple injuries that could benefit from earlier mobilization, ipsilateral forearm fractures (floating

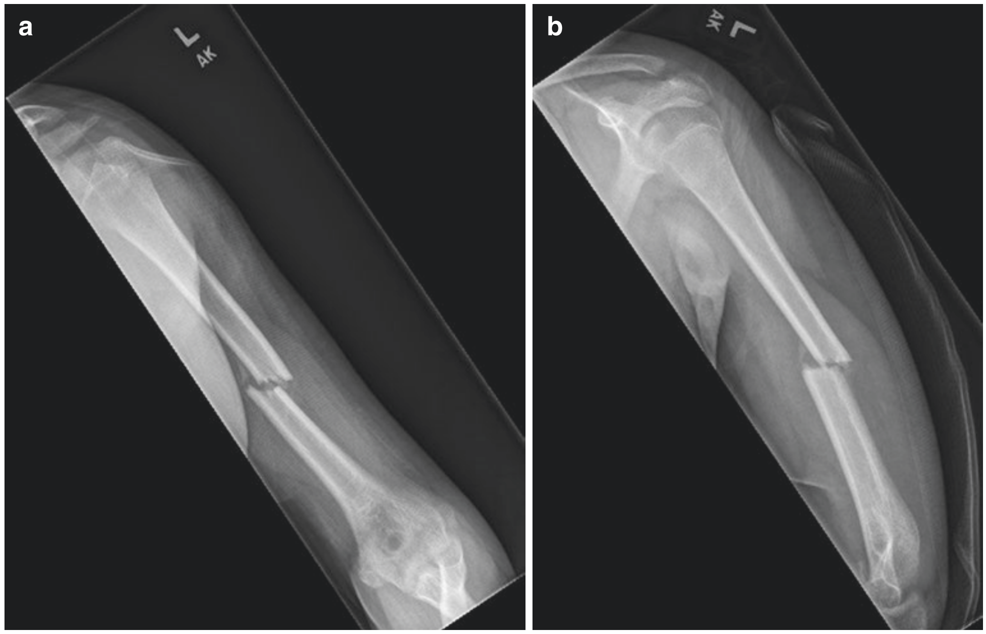

Fig. 15.16 Orthogonal AP (**a**) and lateral (**b**) radiographs of a 13-year-old male who sustained a humeral shaft fracture after a mountain biking accident

Fig. 15.17 Example of a patient being treated with a coaptation splint (**a**), (**b**)

elbow), pathologic fractures, and vascular injury. Radial nerve injuries may not require surgical exploration as most recover over time but an injury should involve consultation with a surgeon [36].

Follow-Up Care

The same as proximal humerus fractures.

Nonoperative

The vast majority of humeral shaft fractures are treated nonoperatively. This is in part due to the extensive range of motion of the shoulder joint, allowing for a large amount of fracture deformity. Acceptable fracture alignment includes 20° of anterior bowing, 30° of varus angulation, 15° of malrotation, and 3 cm of shortening or bayonet apposition [37].

Fig. 15.18 Examples of functional humerus braces (**a**), (**b**)

Follow up is weekly to every other week with repeat radiographs to ensure healing and adequate alignment. The typical healing time is 8–12 weeks [38]. Nonoperative intervention in some studies has shown a higher nonunion rate compared to compression plate fixation, while the rate of transient radial nerve injury was higher in the operative group. Normal range of motion was achieved in both groups [38].

Operative

Operative intervention includes the use of compression plating, rigid intramedullary nails, semi-rigid intramedullary nails.

Return to Sports

There are few evidence-based guidelines for return to play after humerus fractures. Decisions are based on long bone healing physiology, clinical and radiographic healing, and demands of the sport involved. Contact sports may require longer recovery periods than non-contact sports. Gentle range of motion exercises such as pendulums, while in a sling, can be started after 1 week. When there is adequate radiographic and clinical healing, therapy can be started for shoulder and upper extremity strengthening with sport-specific exercises. After the athlete has achieved full shoulder and extremity strength and range of motion, game play can resume. A longer recovery may be needed for sports that apply stress to the humerus including throwing and racket sports and contact sports such as hockey and football.

Complications

Acute complications include neurologic or vascular injuries. Radial nerve palsy can be a significant complication with prevalence approaching 12% of mid-shaft fractures. Transverse and spiral fracture patterns are more commonly associated with palsy versus comminuted and oblique fractures [34].

A long-term complications include nonunion. However, humeral shaft fractures have union rates of 90%–95% with nonoperative and operative treatment [38]. Additionally, with surgical intervention risk of infection, hardware failure, and iatrogenic nerve injury exists as well.

Pediatric Humeral Shaft Fractures

Mechanism of Injury in Sports

The mechanisms of humerus shaft fractures in pediatrics is the same as with adult athletes.

Epidemiology

Less than 3% of fractures in children are mid-shaft humerus fractures. A spiral type fracture is the most common type of mid-shaft humerus fracture in children [39].

Fracture Classification

A specific pediatric humeral shaft fracture classification system is not widely utilized.

Clinical Presentation

In children under the age of 18 months who present with a spiral fracture of the humerus, non-accidental trauma is the most common cause and a thorough investigation is warranted [40]. Children over age of 18 months often sustain fractures from direct trauma to the arm or falling onto a hard object. Non-accidental trauma can still be a cause in children over age 18 months as well, though less likely [41]. In addition, the mid-shaft of the humerus can be common site for pathologic fractures in a child [42]. The injured child may present with swelling, pain. and decreased motion of the injured arm. Diagnosis is made with plain radiographs.

Management

Assess for neurovascular status of the arm distal to the injury and for any evidence of deformity of the arm. The injured arm should be placed in a sling until further assessment can be performed.

Most fractures heal well with sling immobilization or a hanging cast (Fig. 15.19). The mid-shaft of the humerus has less remodeling potential than the proximal humerus, but most fractures still have an excellent prognosis to heal nonoperatively. Children under age 12 with minimal displacement or angulation can be treated with a sling and swath. Adolescent should be treated as adults for mid-shaft humerus fractures. Healing in children typically will take 4–6 weeks [39].

Fig. 15.19 Example of a patient being treated with a hanging arm cast

Indications for Orthopedic Referral

Emergent referral is indicated with any sign of neurovascular compromise, open fracture, or gross deformity or for concern of non-accidental trauma to the child. Urgent referral is also necessary with any concern for pathologic fracture, if the treating physician is not comfortable with the fracture or if the treating provider is unsure if the fracture needs further reduction.

Return to Sports

Return to sports can be considered when the young athlete has no pain on exam, full range of motion of the arm at the shoulder and elbow, and evidence of complete healing on plain radiographs.

Complications

Complications are not very common for mid-shaft humerus fractures in children. Radial nerve injury can occur, but this is less frequent in children compared to adults. Some mild angulation, shortening or overgrowth of the humerus may occur after the injury heals, but this rarely interferes with arm function [39].

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