BRITISH JOURNAL OF HOSPITAL MEDICINE

Humeral shaft fractures: a practical guide to assessment and management

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Abstract

Fractures of the humeral shaft represent roughly 5% of all fractures. They occur in an approximate bimodal distribution, typically affecting young adults following trauma and older females after low energy falls in the presence of osteoporosis. Humeral shaft fractures are associated with pain, temporary disability and a reduced quality of life for the duration of treatment. Treatment goals are directed towards achieving and maintaining a fracture environment conducive to healing, pain relief and early restoration of function. While most humeral shaft fractures are conservatively managed, operative management is indicated in certain circumstances. This article provides an overview of these fractures, including their initial management approach and definitive treatment.

Key words: Fracture; Humerus; Humeral shaft; Trauma

Submitted: 8 November 2020; accepted following double-blind peer review: 27 January 2023

How to cite this article:
Dowlut N, Horlick S, Ather S, Gwilym S. Humeral shaft fractures: a practical guide to assessment and management. Br J Hosp Med. 2023. https://doi.org/10.12968/hmed.2020.0653

Basic anatomy of the humerus

The proximal end of the humerus articulates with the glenoid cavity of the scapula to form the shoulder joint. Proximally, the humerus consists of a 'head' (that projects superiorly, medially and slightly posteriorly) and the greater and lesser tuberosities (**Figure 1**). The greater tuberosity is the insertion point of three of the four rotator cuff muscles (supraspinatus, infraspinatus and teres minor), with the lesser tuberosity being the insertion point of the subscapularis muscle. The two tuberosities are separated by a deep groove, the intertubercular sulcus, or bicipital groove, through which the long head of biceps brachii travels. The perisulcal region also acts as the insertion site of the pectoralis major, teres major and latissimus dorsi muscles. The pectoralis major inserts into the crest of the greater tubercle, the teres major into the crest of the lesser tubercle, and the latissimus dorsi into the intertubercular sulcus itself. The anatomical neck of the humerus divides the humeral head from the two tubercles. The surgical neck of the humerus is where the proximal humerus meets the humeral shaft and is in close relation to the axillary nerve and circumflex humeral vessels.

The humeral shaft (diaphysis) occupies most of the length of the upper arm. Proximally, the humeral shaft is circular in cross-section and distally tapers to a more flattened shape. The shaft is an attachment point for several muscles: the deltoid, brachialis, coracobrachialis, brachioradialis and the lateral head of triceps brachii. Consequently, fracture patterns may differ depending on the fracture location and the muscles' pull on the bony fragments. On the posterior aspect of the humerus, a broad, shallow spiral groove travels distally in a medial to lateral direction. The radial nerve courses along this groove between the medial and lateral heads of triceps brachii and, as such, is particularly vulnerable to injury in humeral shaft fractures (**Figure 1**). In this region, the profunda brachii, the first major branch of the brachial artery, supplies blood to surrounding structures.

The distal humerus begins at the distal metaphyseal flares and is characterised by the epicondyles, the capitellum and the trochlea. The lateral and medial (larger and extending more distally) epicondyles are bony prominences that serve as the origins of several muscles located within the forearm. The trochlea is a 'spool-shaped' structure positioned medially, with the rounded capitellum positioned laterally. The trochlea articulates with the trochlear notch of the ulnar, and the capitellum articulates with the head of the radius, together forming the hinge-type elbow joint. When the elbow is flexed, the radial fossa receives the anterior border of the radial head and the coronoid fossa receives the coronoid

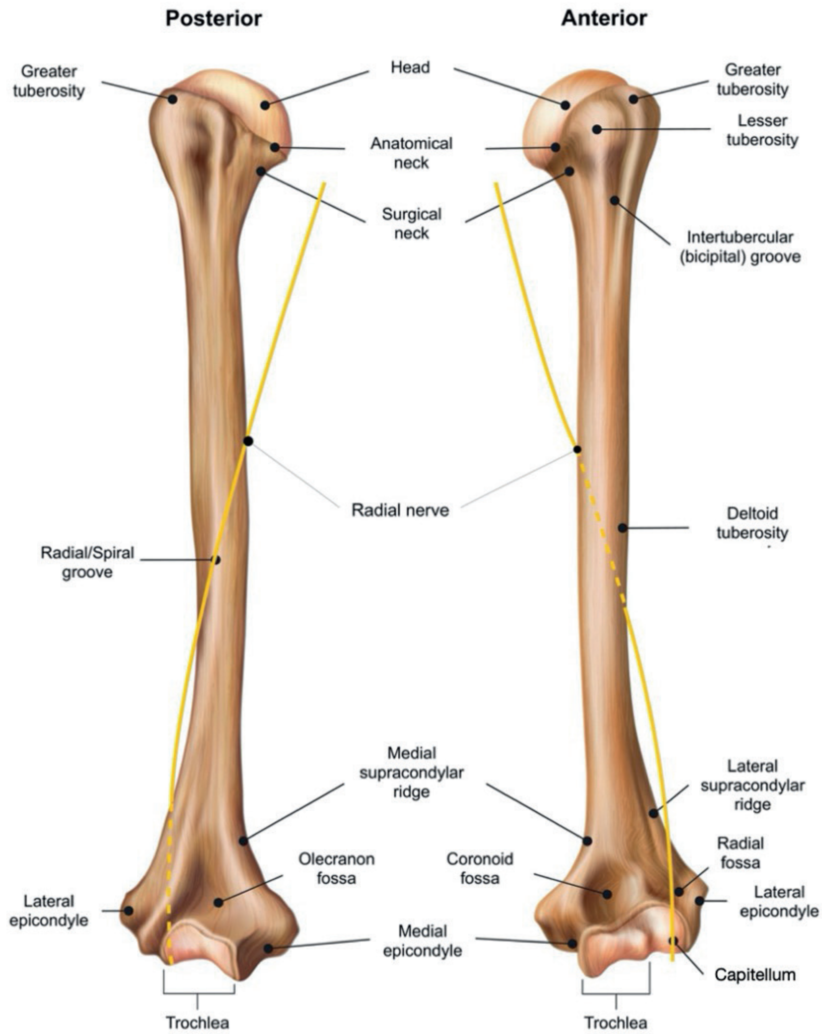

Figure 1. Anatomy of the left humerus and the path of the radial nerve within the arm.

process of the ulna. When the elbow is extended, the deeper, posteriorly sited olecranon fossa receives the olecranon of the ulna.

Epidemiology and classification

Fractures to the humeral shaft account for up to 5% of all fractures (Browner et al, 2014) and approximately 15–20% of humeral fractures, with proximal humeral fractures being the most common (Rose et al, 1982; Kim et al, 2012). Humeral shaft fractures most often occur in early to middle adulthood and/or within the older population (Ekholm et al, 2006; Bergdahl et al, 2016; Ji et al, 2019). Injuries can occur as a result of either direct or indirect force being applied to the humeral shaft, such as indirect force transmitted from the wrist following a fall onto an outstretched hand. As such, humeral shaft fractures in young–middle-aged adults usually follow high-energy or penetrating trauma, whereas those in the older, commonly osteopenic or osteoporotic population, usually follow low-energy trauma, such as falls from standing height (Ekholm et al, 2006).

Humeral shaft fractures can be described by location (proximal, middle or distal), fracture pattern (transverse, oblique, spiral, comminuted), and whether the fracture is open or closed. The AO humeral shaft fracture classification system is widely used in clinical practice, where humeral shaft fractures (attributed number 12 within the classification) are categorised by fracture pattern (uppercase A (simple), B (wedge) or C (complex/multifragmented)) and fracture location (lowercase a, b or c). Table 1 outlines the AO classification, Figure 2 shows a schematic and Figures 3–5 give plain film examples. Type

Table 1. AO classification of humeral shaft fractures				
Type		**Proximal third**	**Middle third**	**Distal third**
A: Simple	Spiral	12A1(a)	12A1(b)	12A1(c)
	Oblique (≥30°)	12A2(a)	12A2(b)	12A2(c)
	Transverse (<30°)	12A3(a)	12A3(b)	12A3(c)
B: Wedge	Spiral	12B1(a)	12B1(b)	12B1(c)
	Bending	12B2(a)	12B2(b)	12B2(c)
	Fragmented	12B3(a)	12B3(b)	12B3(c)
C: Complex	Spiral	12C1(a)	12C1(b)	12C1(c)
	Segmented	12C2(a)	12C2(b)	12C2(c)
	Irregular	12C3(a)	12C3(b)	12C3(c)

From Rommens et al (2018)

A (simple) fractures are the most common, accounting for around 68% of fractures; type B (wedge) accounts for 28% of fractures; and type C (complex) is the rarest, accounting for just 4% of fractures (Tsai et al, 2009).

The fracture pattern observed in humeral shaft fractures is influenced by the mechanism of injury (high- or low-energy, direct or indirect force) and the subsequent pull of muscles acting on the humeral fragments. The most common transverse fractures typically result from direct blows to the humerus, whereas indirect trauma is often a consequence of falls or a twisting motion, such as during arm wrestling, and usually results in spiral or oblique fractures. Comminuted fractures are associated with higher velocity injuries (Shao et al, 2005; Williams et al, 2010). In fractures of the shaft proximal to the deltoid insertion, the pectoralis major adducts and internally rotates the proximal fragment. Shaft fractures distal to the deltoid insertion produce shortening of the humerus, owing to the pull of the triceps brachii and abduction of the proximal fragment. A small minority of humeral shaft fractures are open, in which case the Gustilo–Anderson classification may be used to guide management post-debridement (Kim and Leopold, 2012).

The radial nerve is particularly vulnerable to injury, owing to its close relation to the humeral shaft; studies report the overall prevalence of radial nerve palsies following humeral shaft fractures to be ~12%, more frequently observed with transverse or spiral fractures affecting the middle or distal humeral shaft (Shao et al, 2005; Ilyas et al, 2020). More significant injuries to the brachial plexus and vascular injuries to the brachial artery are uncommon.

Humeral shaft fractures represent 10% of paediatric fractures. They can result from the birth process (from rotation or hyperextension of the upper extremity during delivery), falls, sport-related injuries, high-energy trauma and non-accidental injury (Shrader, 2007; Bullock et al, 2009; Leaman et al, 2016; O'Shaughnessy et al, 2019). The possibility of non-accidental injury, especially in young children, should always be considered by the assessing clinician.

Initial assessment

Patients who have sustained humeral shaft fractures typically present to the emergency department with pain in the affected arm. The initial approach to the trauma patient should follow the Advanced Trauma Life Support principles, with life-threatening injuries being identified and addressed before non-life-threatening injuries, such as humeral shaft fractures. The secondary survey should focus on identification of non-life-threatening injuries. Clinical history from the patient (if cognisant, and/or from witnesses) can help with this, as well as focused clinical examination. In the presence of such fractures, inspection of the injured arm will usually reveal overlying soft tissue swelling, ecchymosis and deformity (shortening and/or angulation). Palpation of the affected arm may elicit localised tenderness,

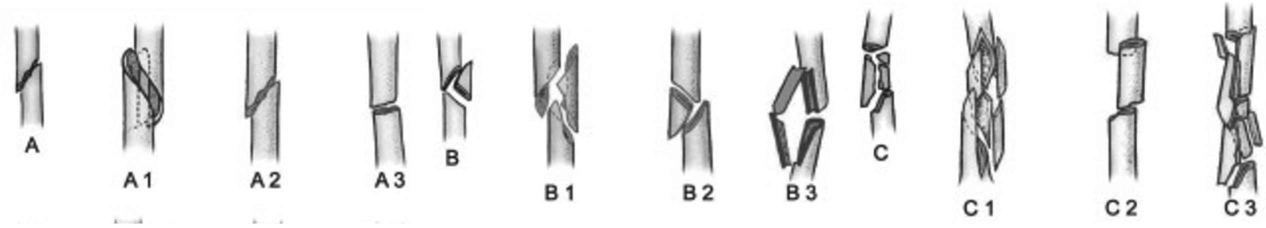

Figure 2. Different types of fracture configurations, as detailed in the AO classification (Benegas et al, 2015).

Figure 3. Spiral fracture to midshaft of humerus: 12A1(b).

Figure 4. Intact wedge fracture to proximal shaft of humerus: 12B2(a).

crepitus and irregularity. When a humeral shaft fracture is suspected, antero-posterior and lateral X-rays should be performed, as well as X-rays of the ipsilateral shoulder and elbow, followed by immobilisation of fractures where present. Reduced patient cognition and concomitant emergent complications, such as haemorrhagic shock from other injuries, can delay initial identification of humeral shaft fractures, making repeated reassessment of trauma patients crucial.

Assessment and documentation of neurovascular status of the patient's arm is vital, both at presentation and following any intervention, such as fracture immobilisation. Functional assessment of the particularly vulnerable radial nerve is essential. Radial nerve injuries manifest as absence or weakness of wrist extension (wrist drop) and finger extension, as well as reduced sensation in the dorsal forearm and the dorsal aspects of digits 1–3.5. Sensation in the first dorsal webspace should be assessed, as this is the only cutaneous region autonomously innervated by the radial nerve. In the event of peripheral nerve injury, the

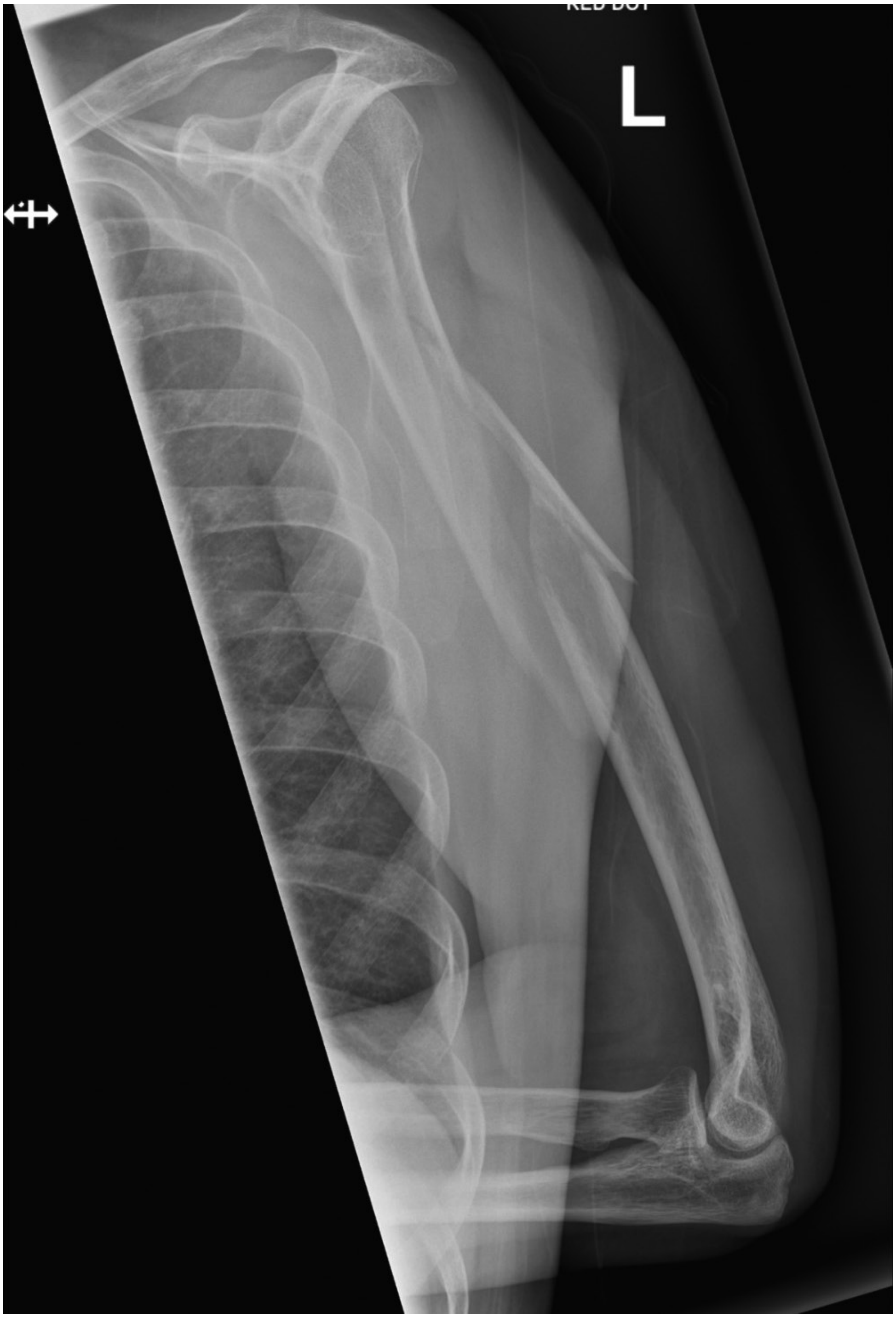

Figure 5. Intact multifragmentary fracture to midshaft of humerus: 12B2(b).

British Orthopaedic Association Standards for Trauma peripheral nerve injury guidelines advocate for urgent reduction and stabilisation (British Orthopaedic Association, 2012). Although infrequently damaged in these injuries, the median, musculocutaneous, ulnar and axillary nerves should also be tested. Table 2 outlines examples of the sensorimotor function of these peripheral nerves that should be assessed during clinical assessment (American College of Surgeons' Committee on Trauma, 2018). Weakness can be graded from 0 to 5 using the Medical Research Council's power assessment scale.

Assessing the vascular status of the arm includes inspecting for pallor and palpating for temperature, capillary refill time and pulses. Although uncommon in humeral shaft fractures, if there is concern about arterial compromise, immediate surgical consultation is

Table 2. Assessment of sensorimotor function of the main peripheral nerves from the brachial plexus fractures		
Peripheral nerve	**Motor function**	**Sensory function**
Radial	Wrist extension, thumb or metacarpophalangeal extension	Dorsal aspect of digits 1–3.5, associated dorsum
Median	Thumb opposition, distal interphalangeal flexion of digits 2 and 3	Palmar aspect of digits 1–3.5, associated palm
Musculocutaneous	Elbow flexion	Radial forearm
Ulnar	Finger abduction, fifth digit flexion	Dorsal and palmar aspect of digits 3.5–5, associated dorsum or palm
Axillary	Shoulder abduction	Lateral shoulder

Adapted from the American College of Surgeons' Committee on Trauma (2018)

advised, as per British Orthopaedic Association Standards for Trauma guidelines (British Orthopaedic Association, 2021).

In the case of open fractures, removal of obvious debris, fracture immobilisation and prompt administration of appropriate intravenous antibiotics are crucial. Once gross contamination is removed, the defect should be covered with saline-soaked gauze and an occlusive dressing, with formal washout, wound debridement and fixation carried out in theatre. The British Orthopaedic Association Standards for Trauma guidelines for open fractures also advocate for the use of clinical photography at key management stages (British Orthopaedic Association, 2017).

Fracture immobilisation, or splinting, involves securing the injured limb in a position that most closely resembles the anatomical position. Reducing motion at the fracture site will reduce pain, prevent further neurovascular compromise and minimise local soft tissue injury. It is important to assess and document neurovascular compromise before and after fracture immobilisation, in case injury is caused during the reduction and immobilisation process. Neurovascular compromise after fracture immobilisation necessitates reversal of the immobilisation and cautious re-attempt. Repeat X-rays should be taken post intervention to assess for satisfactory alignment. Dedicated computed tomography scans are rarely required in the assessment of humeral shaft fractures, although they are useful for assessing fragment position and if there is concern regarding intra-articular fracture extension.

Management

Definitive management of humeral shaft fractures aims to:

1. Achieve and maintain acceptable alignment
2. Provide sufficient stability to enable healing
3. Preserve joint motion.

It is generally accepted that an adequate reduction, resulting in <20° of angulation in the sagittal plane, <30° of varus angulation and up to a maximum of 3 cm of shortening, produces minimal functional or cosmetic deficit. The approach to managing these fractures is influenced by several factors, including fracture classification (open vs closed, presence of joint involvement), isolated injury vs polytrauma, extent of soft tissue injury, presence of vascular or neural injury, bone condition (eg normal, pathological or infected) and patient preference.

Non-operative

The majority of humeral shaft fractures are successfully managed non-operatively. In the conscious and cooperative patient, who has sustained an isolated, simple, closed humeral shaft fracture, with no neurovascular or significant soft tissue injury, the application of a plaster U-slab with collar and cuff, or a coaptation splint, with the elbow held at 90° of flexion, often provides acceptable reduction, enabling satisfactory healing. Alluri and Marecek (2020) have provided a video demonstration of the application of a coaptation splint. Reduction and immobilisation are typically followed by application of a functional brace. Functional bracing is based on the Sarmiento principle (Sarmiento et al, 1977), in which controlled micromovements at the fracture site encourage superior osteogenesis, while mobilisation of the shoulder and elbow joints prevents their stiffness. Bracing permits immediate use of the wrist and elbow for certain activities, while excluding weight bearing and active elevation and abduction, to prevent fracture angulation.

The brace, applied 10–14 days post-immobilisation, is sequentially tightened as soft tissue swelling subsides and is removed once clinical healing has occurred, which is, on average, approximately 8–11 weeks post-fracture (Sarmiento et al, 1977; Papasoulis et al, 2010). Functional bracing generally achieves excellent functional and cosmetic results and is widely considered to be the gold-standard conservative measure for managing these fractures. It is generally well tolerated by patients, although issues can include pressure effects, leading to discomfort and skin breakdown, and unacceptable alignment.

In a systematic review evaluating functional bracing of humeral shaft fractures, Papasoulis et al (2010) reported an average time to union of 10.7 weeks, with an average non-union rate of just 5.5% (range 0–22.6%). Functional bracing was associated with an increased risk of residual deformity compared to operative management, most commonly varus angulation, particularly in patients with short or obese arms. However, varus angulation of <10° was seen in 85% of patients, well below the 30° cut-off for an acceptable cosmetic and functional result, and shortening never exceeded 2 cm (Papasoulis et al, 2010).

Operative

Operative intervention for humeral shaft fractures is indicated in cases of open, pathological or intra-articular fractures, the polytrauma patient; fractures with associated vascular injury, 'floating elbow', or a strong patient preference to operative intervention. Certain fracture locations, such as proximal-third oblique humeral shaft fractures (which are susceptible to soft tissue interposition and the deforming pull of muscles), or fracture patterns in which there is little surface area for plentiful bone to bone apposition (eg transverse fractures), have been shown to be at higher risk of non-union when conservatively managed. As such, while not always definitively indicated, surgeons may also choose to operate in these circumstances.

Operative options include intramedullary nailing, open reduction and internal fixation with plates and screws, including minimally invasive osteosynthesis plates, or external skeletal fixators. While external skeletal fixators are typically reserved for temporary stabilisation where there is significant soft tissue injury, there is no consensus among the surgical community as to the optimal operative management of closed humeral shaft fractures.

Open reduction and internal fixation involves a large incision with extensive soft tissue and fracture site exposure, permitting direct visualisation and rigid fracture fixation. Nails are load-sharing implants designed to minimise fracture disruption and support healing. While open reduction and internal fixation allows anatomical reduction of the fracture and exploration and protection of the radial nerve, there is a theoretical increased risk of infection, iatrogenic damage to the radial nerve and disruption of the periosteum (which plays an important role in fracture healing) compared to nailing. The minimally invasive osteosynthesis plates technique attempts to reduce the exposure and, therefore, the potential risks associated with plating. Risks of intramedullary nailing include greater radiation exposure to the surgeon, iatrogenic fracture and, in the case of antegrade nailing, damage to the rotator cuff.

A systematic review comparing open reduction and internal fixation and intramedullary nailing found no difference in the restoration of patient function between these techniques, with nailing giving a slightly higher complication rate compared to minimally invasive osteosynthesis plates (but not open reduction and internal fixation), largely because of shoulder impairment (Saracco et al, 2022). Beeres et al (2022) performed a meta-analysis of 18 observational studies and ten randomised controlled trials comparing open reduction and internal fixation and nail fixation for humeral shaft fractures. Intramedullary nailing reportedly had a lower risk of infection, postoperative radial nerve palsy and shorter operative duration. However, the nailing was associated with a higher rate of re-intervention, namely for shoulder impingement. No differences between the two treatment modalities

Key points

- Humeral shaft fractures are common, representing up to 20% of humeral fractures.
- When managing humeral shaft fractures, assessment of radial nerve function is crucial, as radial nerve injury is the most common associated neurological injury.
- Many humeral shaft fractures are successfully managed non-operatively, although surgical management is indicated in some cases and is increasingly being performed.
- Further research is required to guide definitive management strategies of these fractures.

were observed when comparing rates of non-union, functional scores and general quality of life, with the authors concluding that both modalities offer satisfactory results.

Management of associated radial nerve injuries depend on their presentation. Indications for acute surgical exploration of the radial nerve are broadly similar to the indications for operative management of these fractures (open fractures, vascular injury or the polytrauma patient), in which case open reduction and internal fixation is preferred over nailing, owing to the exposure achieved allowing radial nerve exploration. If the nerve is lacerated but otherwise appears healthy, the surgeon may consider tension-free repair at the time of fixation. If the nerve appears contused, management options vary and may necessitate input from a specialist peripheral nerve injury centre. In closed fractures managed conservatively, radial nerve injuries are typically managed expectantly, with follow up involving serial clinical examination and electromyograms. Surgical exploration (with possible reconstruction) is typically recommended at 3–5 months from initial injury if there is no evidence of improvement (Daly and Langhammer, 2022).

Although the majority of humeral shaft fractures are managed conservatively, there is some evidence to support faster recovery times and lower non-union rates in operatively managed patients. van de Wall et al (2020) demonstrated higher non-union rates in conservatively managed humeral shaft fractures (15.3% vs 6.4%), with an associated high rate of secondary operative intervention. However, there was no increased risk of permanent radial nerve palsy, disability or time to union. Rämö et al (2020) conducted a randomised controlled trial investigating functional outcomes of patients who were managed conservatively versus those who had undergone open reduction and internal fixation for closed humeral shaft fractures. While functional outcomes at 12 months were similar between the two groups, the rate of non-union in the functional bracing group was 22%, with 30% of patients initially randomised to functional bracing later undergoing operative repair of their fracture.

These rates of non-union observed in conservatively managed groups contrasts with the average non-union rate of 5.3% seen in Papasoulis et al's (2010) review of 18 studies. This highlights the high degree of variability in reported rates of non-union following conservative management, reflective of the heterogeneity of humeral shaft fractures and the patient populations that they affect (Papasoulis et al, 2010). This supports the view of increasing primary operative management of certain subsets of these patients. However, the expense and increased risk of operation-specific complications means that more research is required to identify the specific groups of patients that would benefit from early operative management. The HUmeral SHaft Fracture (HUSH) trial is a multicentre, prospective, randomised superiority trial, commissioned by the National Institute for Health Research, which is currently evaluating outcomes between the two broad treatment strategies, with the hope of providing a definitive comparison of function, cost and risk profiles in patients undergoing surgical and non-surgical management of humeral shaft fractures (https://hush-trial.digitrial.com).

Conclusions

Humeral shaft fractures are common fractures affecting patients of all ages. Radial nerve palsy is often associated with these fractures, and while most will spontaneously resolve, a role for nerve exploration and repair exists in certain settings. While most injuries are successfully managed conservatively, definitive surgical management is appropriate in certain scenarios. Both open reduction and internal fixation and intramedullary nails have been shown to produce acceptable results, with their individual risks. Further research is required to identify patient-specific factors that influence outcomes with the different management strategies, to allow management of these fractures to be optimally tailored going forward.

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Conflicts of interest

SG is the chief investigator of the HUmeral SHaft Fracture (HUSH) trial, which is funded by the National Institute for Health Research. However, this work was not funded by the National Institute for Health Research (or other bodies), and the National Institute for Health Research had no influence on the conception, design, results or preparation of this manuscript.

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