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Paediatric forearm fractures: assessment and initial management

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Abstract

The forearm is the most common site of fracture in children. At the time of initial assessment, a thorough examination and neurovascular assessment of the limb is necessary. X-rays allow evaluation of the fracture location and type, in addition to the degree of displacement. With the help of intranasal opiates, manipulation of fracture fragments can be performed in the emergency department. Immobilisation in plaster is the gold standard treatment for paediatric forearm fractures where the degree of displacement is within acceptable parameters. Manipulation and casting should be followed by orthogonal radiographs and a repeated neurovascular assessment of the limb. Oral analgesia and safety netting information should be provided on discharge and the child should be reviewed in fracture clinic within a week of the injury. This article reviews the British Orthopaedic Association Standards for Trauma and Orthopaedics for the early management of paediatric forearm fractures that do not require operative management.

Key words: British Orthopaedic Association for Trauma and Orthopaedics; Fractures; Paediatric forearm; Paediatric trauma

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Introduction

Forearm fractures are the most common type of fracture in children, accounting for 17.8% of all fractures in individuals under the age of 19 years old (Naranje et al, 2016). These fractures most frequently occur as a result of a fall onto an outstretched hand, especially in the playground setting (Ryan et al, 2010).

The management of paediatric forearm fractures depends on a number of factors including the patient's age, the fracture location, and the degree of displacement. Immobilisation in a cast is the gold standard treatment in the majority of cases (Bowman et al, 2011). However, operative management in the form of K-wires, elastic intramedullary nails or plate fixation may be required if fracture displacement exceeds acceptable parameters.

The British Orthopaedic Association Standards for Trauma and Orthopaedics (BOAST) for the early management of paediatric forearm fractures were published in May 2021 by the British Association of Orthopaedics. These evidence-based guidelines were produced as a collaboration between the Orthopaedic Trauma Society, British Society for Children's Orthopaedic Surgery, and Royal College of Emergency Medicine. These guidelines, which outline the expected level of care for patients in the UK, describe the initial management of paediatric patients with angulated, but not off-ended, forearm fractures (British Orthopaedic Association, 2021). This guideline excludes fractures requiring operative management as a result of either patient or injury-related factors (British Orthopaedic Association, 2021). This article reviews the early management, including diagnosis and initial treatment, of paediatric forearm fractures based on BOAST guidelines.

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Anatomy

The forearm consists of two bones, the radius and the ulna. The ulna is relatively straight and static, playing an important role in maintaining forearm stability, especially when subjected to buckling and torsional stress (Salvi, 2006). The radius rotates around the ulna during pronation and supination along an axis passing obliquely from the distal ulnar head to the proximal radial head (Figure 1). The range of pronation is increased by an apex

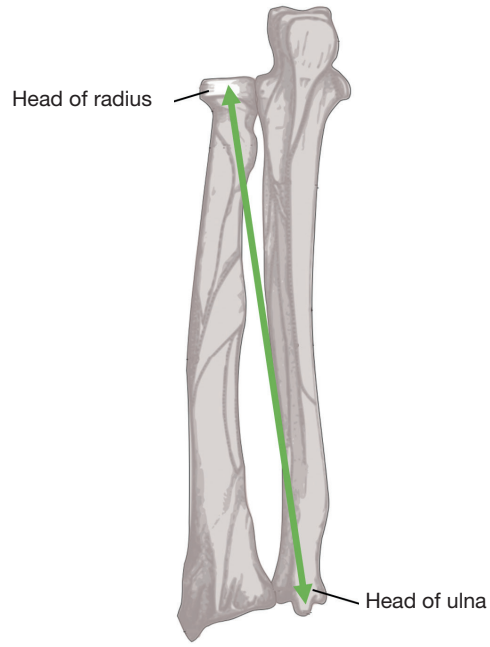

Figure 1. Posterior view of the radius and ulna showing the axis of rotation passing from the proximal radial head to the distal ulnar head.

lateral bend in the radius, termed the radial bow (Firl and Wünsch, 2004). The fibres of the interosseous membrane, which unite the radius and ulna along the diaphysis, are more relaxed in supination and taut in pronation. The two bones are united proximally by the annular ligament, and distally by the ligaments of the distal radioulnar joint and triangular fibrocartilage complex.

Many muscles originate from or insert onto the radius and ulna, influencing the deformity of forearm fractures (**Figure 2**). In the case of a proximal fracture, the supinator and biceps flex and supinate the proximal fragment. In middle third fractures, the pronator quadratus pronates the distal fragment, but the impact of the biceps on the proximal fragment is negated by the pronator teres, causing the proximal fragment to remain in a neutral position. The brachioradialis dorsiflexes and radially deviates the distal fragment in distal third fractures. Understanding these deforming forces is essential in the manipulation and reduction of both-bone forearm fractures (Truntzer et al, 2015; Caruso et al, 2021).

There are several anatomical differences distinguishing the child's and adult's forearm. The proximal and distal physes of the radius and ulna provide longitudinal growth. The distal radial and ulnar growth plates are responsible for 75% and 81% of the longitudinal growth of each bone respectively (Digby, 1916). Furthermore, the radial and ulnar shafts are proportionately smaller in the child's forearm, with a narrow medullary canal (Noonan and Price, 1998). The periosteum in children is also thicker than in adults, explaining torus and greenstick fracture patterns in paediatric patients (Noonan and Price, 1998).

Assessment

Mechanism of injury

At the time of initial assessment, it is important to understand the mechanism of injury. Most of these injuries occur as a result of indirect trauma, most commonly a fall from height. A retrospective study of children with isolated forearm fractures revealed the most common specific mechanism of injury was 'fall from monkey bars', with only 10% of fractures a result of direct trauma (Ryan et al, 2010). This partly explains the seasonal variation of this injury (Ryan et al, 2010).

The mechanism of injury is important for the fracture pattern and degree of displacement. Single bone forearm fractures are more commonly a result of direct trauma, and should raise suspicion for a Monteggia or Galeazzi fracture-dislocation (Caruso et al, 2021).

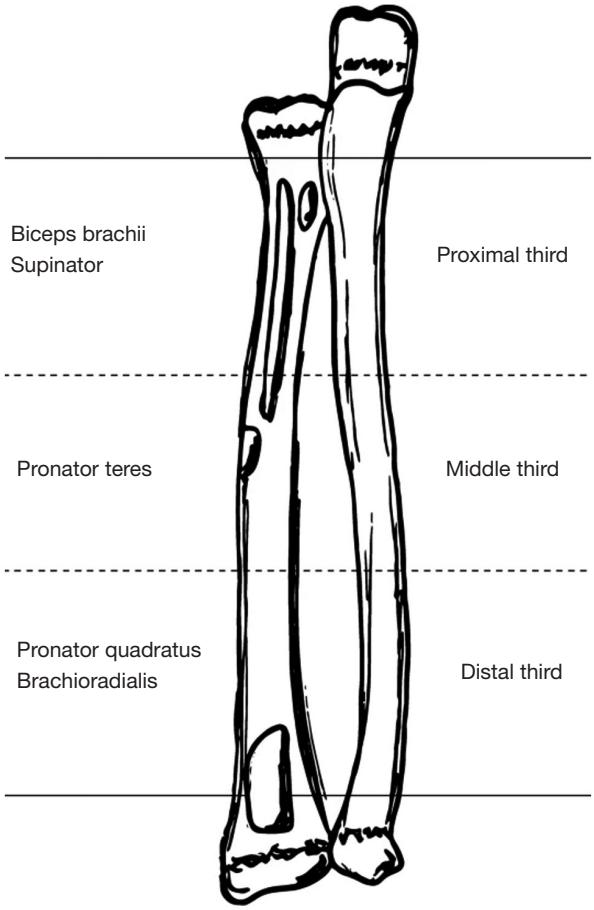

Figure 2. Insertion points of muscle groups of the forearm. Adapted from Caruso et al (2021).

As previously discussed, complete fractures often displace according to the relationship between fracture location and insertion of muscles.

When assessing a child with one or more fractures in the absence of a medical condition predisposing to fragile bones, non-accidental injury should be considered as per National Institute for Health and Care Excellence (2009) guidance. Factors raising suspicion include fractures of different ages, as well as an absent or inconsistent explanation for the fracture (Ryznar et al, 2015).

Initial examination and management

The initial assessment, resuscitation, and management of a paediatric patient involved in trauma should follow the approach outlined by Advanced Trauma Life Support (ATLS) guidance (American College of Surgeons, 2018).

A documented assessment of the limb should be performed at the time of presentation. Skin integrity, swelling and deformity must initially be assessed. Open fractures should be managed in accordance with the BOAST open fracture guidelines (British Orthopaedic Association, 2017). Although difficult to assess in paediatric patients, tenderness and range of motion at the wrist and elbow will help to identify other injuries and rule out Monteggia and Galeazzi injuries, where a single bony injury is associated with a joint disruption at the elbow or wrist respectively.

A full neurovascular assessment should be performed and documented at the time of presentation (British Orthopaedic Association, 2021). An evaluation of vascular perfusion involves palpation of the radial pulse and assessment of capillary refill time. Neurological examination of the upper limb can be challenging in children because of difficulties with understanding and compliance. A simple game of rock-paper-scissors to assess motor function of the upper limb has been described: the median nerve flexes the wrist and fingers to make ‘rock’, the radial nerve extends the metacarpophalangeal joints to make ‘paper’,

and the ulnar nerve abducts the first and second digit to make 'scissors' (Davidson, 2003). Additionally, the 'Ok sign', with the thumb and first finger making a circle, can be used to assess the anterior interosseous nerve (Robertson et al, 2012). Sensory function can be assessed in a similar manner to adult patients.

Effective analgesia should be administered at the time of initial assessment, and should be followed by regular pain scores to ensure that pain relief is maintained (British Orthopaedic Association, 2021). Studies favour the use of ibuprofen rather than paracetamol for paediatric musculoskeletal injuries in the emergency department (Le May et al, 2016).

Investigations

Standard antero-posterior and lateral view radiographs allow the initial diagnosis of paediatric forearm fractures, and help plan further management (British Orthopaedic Association, 2021). If the wrist and elbow cannot be visualised on the forearm X-ray, separate studies should be performed to exclude a supracondylar fracture, radial head dislocation and distal radioulnar joint injury (Noonan and Price, 1998).

Forearm X-rays are important to determine fracture location and fracture pattern. Paediatric fracture patterns are classified as torus, greenstick or complete fractures (Figure 3; Table 1). Physeal injuries are most common during the pre-adolescent growth spurt when growth plates are weakest (Levine et al, 2021). The original Salter–Harris classification describes five physeal injuries: type I involves widening of the physis, type II involves a fracture extending through the physis and metaphysis, type III involves a fracture extending through the physis and epiphysis, type IV involves a fracture extending through the metaphysis, physis and epiphysis, and type V involves a compression injury to the physis (Figure 4).

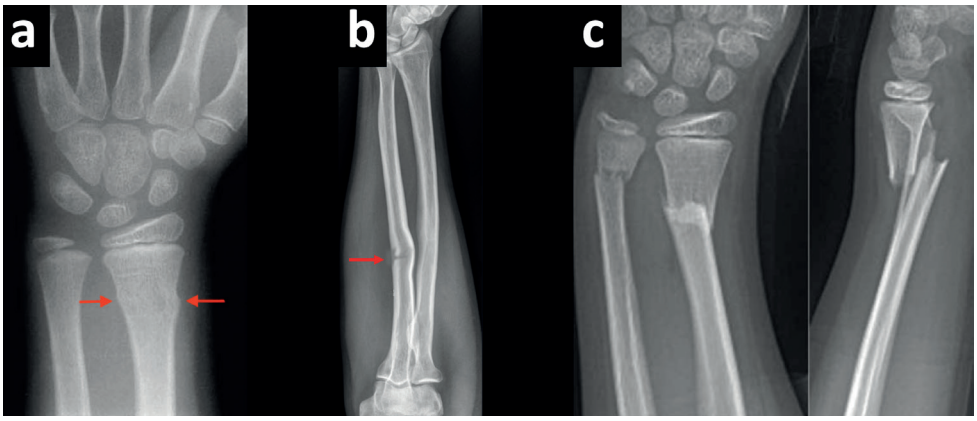

Figure 3. Paediatric forearm fracture patterns. a. Buckle fracture of distal radius and complete fracture of ulnar styloid. b. Greenstick fracture of ulna. c. Complete fractures of distal radius and ulna.

Table 1. Paediatric forearm fracture and injury patterns

Fracture or injury pattern	Description	Mechanism of injury
Torus (buckle) fractures	Compression failure of the bone without disruption of the cortex, resulting in buckling of one or more cortices	Compressive force, usually fall from standing height onto outstretched hand
Greenstick fracture	An incomplete fracture involving cortical disruption on the tension side of the fracture, but intact cortex on the compression side	Fall onto outstretched hand
Complete fracture	A fracture where there is disruption of the entire cortex	Direct or indirect trauma, high energy
Galeazzi fracture-dislocation	Fracture of the distal third of the radius and dislocation of the distal radioulnar joint	Fall onto outstretched hand
Monteggia fracture-dislocation	Fracture of the ulnar and dislocation of the proximal radius (radial head)	Fall onto outstretched hand, with elbow hyperextension

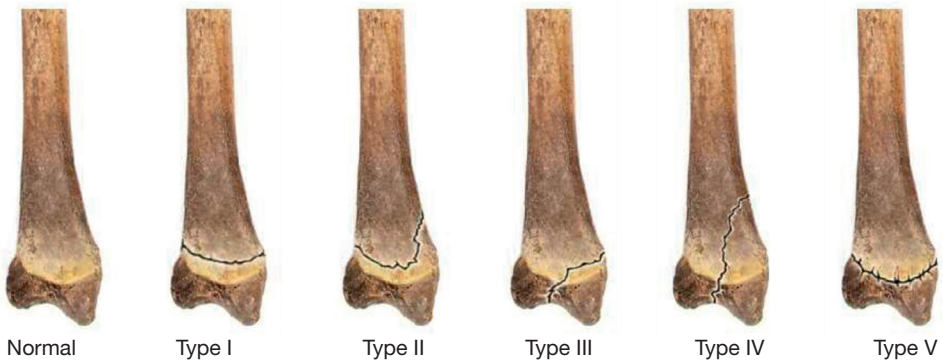

Figure 4. Salter–Harris classification for physeal injuries. Adapted from Levine et al (2021).

X-rays are necessary to determine displacement, angulation and rotation of fracture fragments, all of which are important for fracture remodelling. It can be difficult to estimate rotational deformity of forearm fractures based on an X-ray; however, a rotational deformity of fracture fragments should be suspected if a mismatch exists between the diameter of these fracture fragments. Alternatively, assessment of rotational alignment can be helped by comparison X-rays of the opposite forearm in a similar position (Creasman et al, 1984).

Management

Following radiographic evaluation of paediatric forearm fractures, immobilisation in plaster with or without manipulation is necessary. Immobilisation in plaster in the acute setting helps to maintain bone alignment and protect the injury while also helping to reduce pain (Boyd et al, 2009).

Operative management of paediatric forearm fractures is indicated when closed management fails or has a high likelihood of an unsatisfactory outcome (Price, 2010). Acceptable alignment patterns for paediatric forearm fractures have been proposed (Table 2), but remain controversial (Price, 2010). The majority of forearm growth occurs at the wrist, so the remodelling potential of distal forearm fractures is greater (Noonan and Price, 1998). The optimal management of even severely displaced paediatric distal radius fractures is under debate; the Children's Radius Acute Fracture Fixation Trial (CRAFFT), which aims to report in 2025, is a multicentre randomised controlled trial aiming to compare outcomes of surgical vs non-surgical management of these fractures. Patients with open or multiple fractures, neurovascular injury or adjacent joint dislocation often require internal fixation in theatre (Price, 2010). Although important, the decision to proceed with operative management is beyond the scope of the BOAST for early management of forearm fractures, and hence beyond the scope of this review.

Manipulation and immobilisation

Closed reduction of forearm fractures in children should be performed by orthopaedic practitioners who are competent in manipulating paediatric fractures (British Orthopaedic

Table 2. Acceptable early alignment parameters for displaced paediatric forearm fractures

Fracture location	Age	Angulation	Rotation
Distal third and mid-shaft fractures	<8 years old	<15°	<45°
	>8 years old with >2 years of remaining growth	<10°	<30°
Proximal shaft fractures	<8 years old	<10°	<30°
	>8 years old	Consider anatomical reduction with internal fixation	

Association, 2021). Manipulation should be performed in a suitable location equipped with facilities to allow effective treatment and casting, as well as monitoring and management of possible post-procedure complications (British Orthopaedic Association, 2021). Additionally, the child (if competent), carers and clinicians should agree with the intervention, and this should be documented in the patient's notes (British Orthopaedic Association, 2021).

Manipulation of paediatric forearm fractures is commonly performed under conscious sedation in the emergency department. A retrospective study by Chan et al (2020) showed that closed reduction of paediatric forearm fractures using nitrous oxide and intranasal fentanyl is a safe and effective alternative to closed reduction under general anaesthesia, with comparable outcomes.

Following administration of necessary medication, manipulation of the forearm fracture involves first recreating the initial deformity, and then providing traction to obtain the appropriate length, while reducing angulation or rotational deformity of the fracture fragments (Vopat et al, 2014). While the arm is still in traction, if alignment is appropriate, the cast is applied. The hand is positioned in neutral or slightly supinated, with the wrist immobilised to prevent pronation-supination of the forearm and further fracture displacement (Vopat et al, 2014). Casts are moulded with three-point moulding, involving anterior and posterior compression over the interosseous membrane, to increase the stability of the cast (Caruso et al, 2021).

Historically, the elbow has also been immobilised at 90° for all forearm fractures, in order to neutralise the deforming forces of muscles originating above the elbow, while also increasing the stability of the cast and preventing the cast from moving distally (Jones and Weiner, 1999; Pretell Mazzini and Rodriguez Martin, 2010). However, it has since been proposed that well-moulded short-arm casts reduce the pronation-supination movements at the wrist with equally beneficial results to above-elbow casts (Webb et al, 2006). Randomised control trials have shown that below-elbow casts are comparable to above-elbow casts for distal forearm fractures in terms of re-displacement (Paneru et al, 2010; Caruso et al, 2019). However, there are not yet any similar studies evaluating below-elbow and above-elbow casts for middle third or proximal third paediatric forearm fractures. Buckle fractures are inherently stable fractures, and hence below-elbow casts are commonly used for this fracture pattern (Primavesi, 2011).

Closed reduction of the forearm fracture should be followed by orthogonal X-rays in the emergency department, to evaluate the results of manipulation and plan further management (British Orthopaedic Association, 2021). An assessment of the neurovascular status of the limb, as described previously, should be repeated and documented following closed reduction and immobilisation (British Orthopaedic Association, 2021).

Follow up

Before discharge from the emergency department, oral analgesia should be provided to take home (British Orthopaedic Association, 2021). There has been a reluctance to prescribe non-steroidal anti-inflammatory medications because of fears that these delay fracture healing. However, Nuelle et al (2020) showed that ibuprofen is an effective analgesic in children with musculoskeletal injuries and its use does not impair fracture healing clinically or radiologically in skeletally immature patients.

Common complications of immobilisation in a cast should be discussed before discharge. These include loss of reduction (even a properly reduced fracture may drift into further angulation in the cast in the early phases of healing; Price, 2010), muscle atrophy and elbow stiffness (Chia et al, 2015). Disuse osteopenia has also been described as a possible complication of immobilisation, with the risk being higher among adolescent patients (Ceroni et al, 2012). Synostosis can occur as a result of closed reduction of forearm fractures with an increased risk following high-energy injuries or multiple attempts at reduction of a proximal third forearm fracture (Chia et al, 2015). The risk of compartment syndrome in closed paediatric forearm fractures has been estimated as less than 1%; this risk is higher with open forearm fractures (Hak, 2019).

Patients and their carers should be given safety-netting advice and contact details before discharge (British Orthopaedic Association, 2021). Red flag symptoms, which

Key points

- Initial assessment of the child should include a history to understand the mechanism of injury and examination to assess deformity and soft tissue injury. A detailed neurovascular assessment of the limb should be performed and documented.
- Analgesia should be administered at the time of initial assessment and before any manipulation.
- X-rays allow the fracture pattern and the presence of physeal injury to be identified, as well as the degree of displacement, angulation and rotation of fracture fragments.
- An understanding of the deforming forces can help in the manipulation of forearm fractures. Manipulation should be followed by the application of a well-moulded cast, a neurovascular assessment of the limb, and repeat X-rays.
- The case and images should be reviewed by an orthopaedic consultant within 48 hours, and the patient should be reviewed in fracture clinic within 7 days of injury.

should prompt further medical review, include any new or worsening neurovascular symptoms, or worsening pain.

A fracture clinic appointment should take place within 7 days of the injury (British Orthopaedic Association, 2021). Finally, the case and images should be reviewed by a consultant orthopaedic surgeon within 48 hours of the injury, and the findings documented (British Orthopaedic Association, 2021).

Conclusions

The majority of paediatric forearm fractures can be managed non-operatively. Appropriate management of these patients involves a history, examination and completion of X-rays at the time of initial assessment, followed by casting with or without manipulation to restore fracture alignment.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

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Curriculum checklist

This article addresses the following requirements from the trauma and orthopaedics curriculum:

- Know specifically and broadly the anatomy of bones and joints in the growing child and its application to growth and deformity.
- Clinical assessment of paediatric patients: history and examination of the child, involving the parents in the assessment, assessing the child with possible non-accidental injury
- Applied clinical skills: fracture of the shaft of radius or ulna manipulation under anaesthesia and plaster of Paris application.

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