1. Introduction

Fractures are almost a normal part of childhood - some 30% to 60% of children will suffer a fracture during their growing years [landin, other]. Children have tough periosteum which limits the displacement of fractures and speeds their healing. They have active growth from the physeal plates which aids in remodeling and allows children to tolerate malunion in most regions. A lot of children’s fractures are straightforward to look after and good results can be obtained with minimal intervention.

The elbow can be different. It is an anatomically busy area with six centres of secondary ossification meaning many different types of fractures can occur. Small fragments can be difficult to control with plaster immobilization alone, and both malunions and frank nonunions can occur. Swelling of the soft tissues can lead to compartment syndrome, especially if flexion of the elbow puts pressure on the antecubital fossa. Damage to nerves and blood vessels is common at the time of fracture. The young surgeon may face confusion about the diagnosis or the best treatment, and concern about the potential for disabling complications. This review aims to settle the confusion, and allow the surgeon to prevent the complications.

This review is based heavily on the practice of elbow fracture management and is prepared to support the Paediatric Fractures course at COSECSA in Lusaka on Dec 3-4 2011. A commentary on evidence based guidelines appears at the end of the review.
2. Mechanisms of Injury

Falls cause most childhood fractures. Toddlers fall when they are learning to stand and walk. Schoolchildren fall when they are learning to climb and play. Older children and teenagers fall as they compete on the sports field.

Falls from above the child’s own height are 3 to 5 times more likely to cause severe fractures than are standing height falls [fiisel]. Even if falls cannot be prevented, many fractures can be prevented by using appropriate energy absorbing surfacing where children may fall off play equipment. In a randomized controlled trial in Toronto, granitic sand was shown to be superior in preventing fractures from playground equipment falls [howard].

The surgeon must always keep in mind the possibility of an inflicted injury (child abuse) when evaluating any child with a fracture. Although some fracture patterns (for example a metaphyseal corner fracture) are highly associated with child abuse [ref], the most common fractures occurring among abused children are the common fractures we see from other mechanisms as well (1). Clinical features associated with inflicted injuries include delay in seeking care, injuries not consistent with the history given, multiple fractures, healing fractures, skin bruising or marks in abnormal areas, and fractures, head injuries, or retinal hemorrhages in the very young - particularly those below walking age (1,2). There is potential for a fatal outcome from repeated abuse so the surgeon must follow through in suspicious circumstances and take steps to protect the child if necessary (3).

Mechanism of injury is important in determining the risk of complications. Higher kinetic energy injuries (for example road traffic injuries or falls from heights) produce greater disruption of bone and soft tissue and are more likely to lead to complications from swelling or from nerve or vessel damage.

3. Anatomy of the Growing Elbow

At birth the primary ossification centres of the shafts of the humerus, radius, and ulna are all that is visible on a plain Xray and the elbow joint just looks like a big gap. The ossification centres appear in the following order and at the approximate ages:

<table>
<thead>
<tr>
<th>Ossification Centre</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capitellum</td>
<td>2</td>
</tr>
<tr>
<td>Radius (proximal)</td>
<td>4</td>
</tr>
<tr>
<td>Internal (Medial Epicondyle)</td>
<td>6</td>
</tr>
<tr>
<td>Trochlea</td>
<td>8</td>
</tr>
<tr>
<td>Olecranon</td>
<td>10</td>
</tr>
<tr>
<td>External (Lateral Epicondyle)</td>
<td>12</td>
</tr>
</tbody>
</table>

By maturity all of these secondary centres have fused to their respective primary ossification centres and this fusion occurs in approximately the same order as their appearance.

Growth in the upper limb occurs mostly at the distal radius and the proximal humerus, with less than 30% of it occurring at the elbow. (This is opposite to the lower extremity where most growth occurs at the knee). Less growth means less remodeling so malunions at the elbow tend to persist, especially varus or valgus malunions which are not in the plane of motion of the joint.

On the other hand, the chance of a clinically significant deformity from a partial growth arrest is lower in the upper limb than it is in the lower limb after adequate reduction of a fracture which crosses the growth plate. This is because of the slower growth of the elbow, and also because it takes less kinetic energy to fracture the distal humerus than it does to fracture the distal femur.

4. Fracture Types - Acute

4.1 Supracondylar Humerus Fracture

The supracondylar humerus fracture is the most common fracture around the child’s elbow. The usual mechanism of injury is a fall onto the limb with the elbow hyperextended and locked(a few degrees of hyperextension is normal for children). The fracture force produces an apex anterior deformity with the small distal fragment usually posteriorly displaced behind the shaft. In the coronal plane there may be either medial or lateral translation, and either varus or valgus angulation. Typically the distal fragment is internally rotated with respect to the proximal one. Displacement may be marked, with the shaft fragment compromising or piercing the skin anteriorly, and with the distal fragment posterior to the shaft and in a shortened position.

Minimally displaced fractures may be managed with a posterior backslab to immobilize for comfort, the fracture will be healed in about three weeks (4) (5). Evaluate the films carefully because apparently minimally displaced fractures can produce varus malunions. In the author’s practice, reduction is recommended if the capitellum has displaced posterior to the anterior humeral line. Baumann’s angle, measured on the AP Xray, should be between 72 and 82 degrees, and is the best measure for quantifying varus displacement. Comminution in the medial metaphysis or gaps in the lateral fracture line may also indicate a varus malunion. Most malunions in the author’s (North American) referral practice come from minimally displaced fractures which were not reduced, rather than from fully displaced fractures which were reduced and pinned.

http://www.ptolemy.ca/members/current/Elbow%20Fractures/index.html  2011/11/02
Figure 1a – The anterior humeral line (orange) should cross the capitellum. Here there is a supracondylar fracture angled in extension, and the capitellum is displaced posteriorly to the anterior humeral line.

Figure 1b – Baumann’s Angle – this allows evaluation of varus or valgus malposition and should measure between 72 and 82 degrees.

With a displaced fracture the immediate concerns include a careful evaluation of the neurological and circulatory status of the hand and forearm as well as the amount of local swelling and the condition of the skin over the fracture. Splinting the arm in a comfortable position with 30 to 45 degrees of elbow flexion will improve comfort without placing too much pressure in the antecubital fossa.

Figure 2 – A displaced extension type supracondylar fracture of the distal humerus in a child. Controlling the position of the small distal fragment is easiest with closed pinning.

Fully displaced fractures will unite, but varus malunions are common. The varus malunion occurs because the humeral metaphysis is wide on the AP projection but narrow on the lateral projection, and the medial portion of the distal fragment will rotate posteriorly (i.e. internal rotation) then tip into varus unless it is maintained in an absolutely anatomical position.

Traditional management of this fracture relied the intact posterior periosteum to maintain the stability of a closed reduction. This technique is no longer recommended because the forced flexion required to maintain stability of the fracture leads to excessive pressure in the antecubital fossa and increases the risk of compartment syndrome.

If an image intensifier is available then the best management is to perform an anatomical closed reduction of the fracture then hold it in position with two or three pins introduced from the lateral side of the distal fragment (6-13). With the pins holding the distal fragment in place the arm can be splinted in 45 degrees of flexion, a safe position for the swelling and circulation. Laterally introduced pins are preferred to crossed pins because there is a 2% to 6% risk of iatrogenic ulnar nerve injury if a pin is placed from the medial side (14). If lateral pins are spread adequately at the fracture site, they are equally effective at preventing displacement of the fracture. Typically the fracture is healed and the pins can be removed in three to four weeks, with resumption of full activities a month later.

Figure 3a – Lateral entry pinning of a displaced supracondylar fracture. Notice that the pins are spread at the fracture site, so both the medial and lateral column are pinned and the configuration is stable.
In the absence of an image intensifier it is possible to treat the majority of these fractures closed without resorting to dangerous hyperflexion. The patient can be treated in long arm skin traction in an extended position, or with a plaster backslab with the elbow extended, for the first week. At the end of a week the fracture will be sticky with early callus but varus can still be corrected. With the elbow fully extended the arm can be positioned with the elbow in valgus and a molded cast can be applied in this position. Although the reduction may not be anatomic, the functional and cosmetic results will be very acceptable provided a varus malunion can be avoided. There is very little empirical literature on the results of closed treatment of supracondylar fractures, since the vast majority of papers come from centres where image intensifier is available and pinning is the norm. In comparative series the results of pinning are better than those of closed treatment (15) (16) (17), but more work is needed from resource constrained areas particularly regarding closed treatment that avoids severe flexion.

4.2 Lateral Condyle Fracture - Acute

Lateral condyle fractures occur again from a fall on the outstretched extremity. In this case the lateral condyle of the elbow is either pulled off by a varus force, or pushed off by a valgus force.

A lateral condyle fracture is intraarticular, and is also a Salter-Harris type 4 fracture because it crosses the growth plate. The lateral condyle fragment which breaks off includes a large part of the epiphysis (the capitellum) and also includes a small piece of posterolateral metaphysis. If the fracture is displaced it will require an open reduction in order to align the joint line and the growth plate accurately under direct vision.

Minimally displaced fractures should be evaluated with a fifteen to twenty degree internally rotated oblique radiograph since that is the view which will show the maximum displacement. The posterolateral metaphyseal fragment, which is well demonstrated with this view, should be essentially anatomically reduced if the fracture is to be successfully treated by closed immobilization. If the displacement on this or any other view is two
millimetres or more, then an open reduction and internal fixation is recommended to minimize the risk of a nonunion (18). If the fracture is treated closed then a radiograph taken at four weeks should show periosteal new bone linking the metaphyseal part of the fracture and a final radiograph should be taken several weeks later to confirm that the union is complete and maturing. Nonunion can occur in undisplaced or minimally displaced fractures because of the intraarticular nature of the injury, the risk of this happening may be 15% to 20%, and management is discussed below in the section on delayed presentations.

Open reduction and internal fixation can be achieved through a 2 to 3 cm lateral incision over or just anterior to the supracondylar ridge. A slightly anterior incision makes a better scar. Often the fracture hematoma and the elbow joint can be entered readily once the skin incision is made. Expose the fragment and the fracture line anteriorly, but avoid posterior dissection in order to preserve the blood supply of the capitellum. Visualization can be improved with long right angle retractors to gently lift the soft tissues anteriorly, with a headlight, or with a sterilized dental mirror to visualize the joint line. Once anatomic reduction of the joint line and growth plate is confirmed, the fracture can be held with two k-wires introduced through separate stab incisions and left long outside the skin. These k-wires can be removed at an office visit in 3 to 4 weeks time when the fracture is healed (18,19).

4.3 Elbow Dislocation

Dislocations of the elbow are common in children and can be readily reduced with either gentle traction on the forearm or gentle thumb pressure on the olecranon. Usually the reduction is both definite and stable. Carefully evaluate the post reduction radiographs to confirm that the reduction is concentric, and to look for the fractures which may commonly accompany an elbow dislocation - medial epicondyle, lateral condyle, and radial neck fractures are the most common. With a concentric reduction, and without an accompanying fracture, the joint can be immobilized for comfort for about two weeks. Longer periods of immobilization can lead to permanent stiffness of the elbow.

4.4 Medial Epicondyle Fracture

This fracture can occur either in isolation, or accompanying a dislocation of the elbow. The medial epicondyle is a small secondary centre of ossification - an apophysis - on the medial side of the elbow. It is an anchor point for both the ulnar collateral ligament complex and the flexor pronator mass. The mechanism of injury is a posterior dislocation and or a valgus force which avulses the epicondyle under tension.

Medial epicondyle fractures are among those commonly missed on initial presentation. Evaluating the films carefully both for small fragments, and for an ‘empty fossa’ where the medial epicondyle should be, as well as careful palpation of the region will help with timely diagnosis.

The classic closed reduction maneuver is called the Robert’s maneuver, removing an entrapped medial epicondyle fracture from the joint by extending the wrist and fingers while pronating the forearm with a valgus force on the elbow. This maneuver tensions the flexor pronator origin attached to the fragment and can work well in conjunction with reducing a dislocated elbow if a medial epicondyle fracture is identified on the pre-reduction films.

If a medial epicondyle fragment is trapped within the elbow joint or if the fracture is accompanied by a dense ulnar nerve palsy these are considered absolute indications for medial open reduction because leaving either the fragment or the ulnar nerve interposed in the joint will lead to a bad outcome.

Figure 4c – A medial epicondyle fragment trapped within the elbow joint is visible on this lateral view (arrow). Note that the ulnohumeral relationship is not concentric because of the interposed piece.

If the fragment is not entrapped in the joint it is often displaced from its anatomical position and there is controversy regarding whether it should be treated with open reduction and pinning or treated closed (20). In an African setting closed treatment should likely be the mainstay in most circumstances. As with many questions in orthopaedics this has not been settled with a randomized trial nor even a prospective study but there are several retrospective comparative studies and case series which have even been combined in a meta-analysis (21). Treating displaced fractures with immobilization means that many of them go on to a fibrous union, but functional results are excellent and residual symptoms rare. Treating fractures with open reduction and internal fixation gives a higher union of radiographic union but also a higher rate of pain and symptoms on followup. Although all the retrospective literature, including the meta-analysis, is likely biased (by the fact that the fractures which were treated operatively were probably more severe), the absence of any convincing advantage of operative treatment supports a strategy of judicious closed management of this injury in the absence of definite indications such as entrapment in the joint or an ulnar nerve injury.

4.5 Monteggia Fracture - Acute

A Monteggia fracture includes a fracture of the ulna and a dislocation of the radial head. The most common difficulty in management of this injury is identifying the dislocated radial head. Even trained orthopaedic surgeons may miss this ‘obvious’ finding by focusing instinctively on the fractured ulna, and not looking carefully at the radiocapitellar joint. Never believe in an ‘isolated’ ulnar fracture, and always insist on seeing two views of the radiocapitellar joint taken at right angles to ensure that the proximal radius is aligned with the centre of the capitellum.

Among children the ulna may be fractured in the diaphysis, proximal metaphysis, and occasionally as far proximally as the olecranon. Plastic
deformation of the ulna can be the only fracture present - an intact but bent bone - which makes the radius more difficult to reduce. The radial head is most often dislocated anteriorly but it may go laterally or posteriorly. Usually the apex of the ulna fracture points in the direction that the radial head has deformed. If one thinks of the ulnar shaft as a handle for the radial head then a reduction or slight over-reduction of the ulnar fracture will help to reduce and stabilize the radial head by pull on the interosseous membrane. Thumb pressure on the radial head may help in obtaining reduction. Many closed reductions are stable. Examination through a full range of pronation and supination followed by immobilization with 90 degrees of elbow flexion is often successful however weekly radiographic review is recommended to ensure that the radial head is staying in joint.

Figure 5a,b – Monteggia fracture in a child. The ulna is fractured through the metaphysis with apex lateral angulation, and the radial head is displaced from the capitellum laterally and also somewhat anteriorly.

Figure 5c,d – Same child following closed reduction and casting with healed fracture and properly reduced radial head.

If closed reduction cannot be obtained or is unstable, it is always the ulna which is addressed first. The ulna needs to maintain length and stability in order to keep the radial head in joint. In younger children a slight over-reduction of the angular deformity with stabilization of the ulna by an intramedullary steinmann pin or k-wire is often all that is necessary. This type of fixation may not be adequate to maintain ulnar length in an older child or with an oblique or comminuted ulnar fracture pattern, in which case plating the ulna out to length is recommended. Some authors have recommended that all ulnar fractures be plated because of a higher rate of redisplacement with pinning techniques - this certainly emphasizes the importance of maintaining ulnar length in order to maintain reduction of the radius.

4.6 Radial Neck Fracture

Fractures of the radial neck occur in children where an adult might sustain a fracture of the radial head - a compressive load from a fall on the outstretched hand. The usual fracture pattern is a Salter - Harris II type fracture, with the epiphysis and a small triangle of metaphysis displaced. The degree of displacement affects the biomechanical outcome because the disc of the proximal radius will no longer be centred on the capitellum and the more it behaves as a cam, the more likely it is to enlarge and articulate abnormally over the long term. These fractures often occur in adolescents with limited remodeling potential. Opening the joint to perform a reduction increases compromises the outcome, so treatment presents a dilemma.

The solution to the dilemma is to obtain an accurate, near-anatomic closed reduction in as many cases as possible. Multiple methods of manipulation have been described to aid in obtaining a closed reduction. Traditionally the first manoeuvre is to apply lateral thumb pressure while pronating and supinating the radius with some varus stress to open the joint. This will often lead to a reduction. If it does not, then a closed reduction may be obtained by deeply flexing the elbow after rotating the free fragment to the anterior part, or by wrapping the arm in an esmarch bandage.

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If closed reduction fails, it may be augmented by percutaneous techniques using c-arm guidance. Manipulating the fragment directly with one or two k-wired will often allow a full anatomical reduction. If necessary this may be augmented by the Metzau technique, introducing a k wire with a bent tip from the radial styloid and passing it through the medullary canal to the fracture site, where it can be used to refine the reduction by rotation/translation, and can also be used for fixation of the fracture. During any of these percutaneous techniques the posterior interosseous nerve must be protected by pronating the arm to move it forwards, and staying proximal and lateral with the wires to avoid the supinator muscle mass.

**Figure 6** – Percutaneous reduction of a radial neck fracture using a k-wire.

**Figure 7a** – an irreducible radial neck fracture showing an attempt to reduce by thumb pressure from the outside

**Figure 7b** – the same fracture with an intramedullary nail in place

**Figure 7c** – Following rotation of the nail and complete reduction

Many authors feel that it is better to accept an imperfect closed reduction than to do too many open reductions, because of the problems of stiffness, subluxation, and avascular necrosis seen after open techniques (22). This has led to odd appearing ‘algorithms’ such as attempting a closed reduction for any displacement more than 30 degrees, but accepting up to 45 degrees of displacement before proceeding to an open reduction. An open reduction can be performed through a Kocher lateral approach to the elbow between anconeus and extensor carpi ulnaris, again with attention to avoiding the posterior interosseous nerve. Temporary k-wire fixation of the fragment is often used after open reduction.
4.7 Olecranon Fractures

Olecranon fractures are a tensile failure of bone with triceps force during a fall onto the arm. They are common in adults but uncommon in children. Fifty percent of children with olecranon fractures have osteogenesis imperfecta (23), it is not surprising that tensile failure of bone occurs because the primary defect in osteogenesis imperfecta is in collagen formation. Open tension band wiring and early motion as used in adults produce good results.

5. Fracture Presentations: Delayed

5.1 Supracondylar Humerus Fracture - Varus Malunion

It is common to see varus malunions of supracondylar fractures in regions where children do not routinely undergo reduction and fixation. A ‘gunstock’ deformity of the elbow is the typical description - it is a combination of internal rotation, extension, and varus. This is primarily a cosmetic problem rather than a functional problem for the arm. Because the varus is not within the plane of motion of the elbow, it tends not to remodel. Multiple means of performing a corrective osteotomy have been described. The French technique includes a simple lateral closing wedge, leaving a small hinge of medial metaphysis, and closing the osteotomy by tightening a wire around screws placed above and below. This simple osteotomy has had better results than a ‘dome’ osteotomy in comparative series (24). If the medial hinge of metaphysis breaks, k-wires can be added for stability in younger children, or a plate in older children. In either of these circumstances the distal fragment may be translated medially to reduce the lateral...
prominence and improve the cosmetic results. Although varus malunions are common, it must be remembered that the correction is strictly optional and involves a trade-off between an improved appearance of the arm, but a risk of delayed union, malunion, nerve injury, and elbow stiffness (25).

5.2 Lateral Condyle Fracture - Nonunion

A lateral condyle fracture is one of the few paediatric fractures where nonunion is actually a common outcome if treatment is minimal or delayed. This is because the fracture line is bathed in joint fluid and bony union is inhibited. Children with a lateral condyle malunion usually gain full or nearly full motion and have surprisingly little in the way of symptoms. The elbow is usually in a valgus position due to shortening on the lateral side, and the tendency is for the valgus deformity to increase as the years pass. The medium term morbidity associated with this is a tardy ulnar nerve palsy (26). With increasing valgus the ulnar nerve is vulnerable and a progressive ulnar neuropathy including both sensory and motor symptoms can begin between ten and twenty years after the fracture. Correction of the nonunion will prevent both the progression of the cosmetic deformity as well as the development of ulnar neuropathy so should be considered.

An established nonunion is accompanied by substantial growth of the bony metaphyseal fragment on the distal piece. Placing a compression screw percutaneously from metaphysis to metaphysis will achieve fracture union in over 80% of cases, and can be repeated with a larger screw if union is not achieved first time around. This technique avoids stiffness, infection, and avascular necrosis which have been associated with techniques involving opening the joint and taking down the nonunion site.

Figure 10a – A lateral condyle malunion which presented six months after injury. Note the large metaphyseal fragment.

Figure 10b – The same fracture following percutaneous compression screw fixation from metaphysis to metaphysis, showing good bony union.

5.3 Monteggia Fracture - Delayed

Children with a missed Monteggia lesion often present with the ulna healed and the radial head still out of joint. This is difficult to treat and almost always results in some residual loss of pronation and supination even with successful reconstruction. If reconstruction is to be attempted it is best done once the child has had a few weeks to regain motion and is no longer stiff, rather than operating on a child who has recently been immobilized in a plaster cast.

The key to maintaining a reduction of a delayed monteggia fracture is to restore both the length and the angular alignment of the ulna. This will require an osteotomy of the ulna and may require bone grafting to restore length. Plate fixation of the ulna is preferred. In many cases an open reduction of the radial head will also be required. Reconstruction of the annular ligament is the final step in maintaining reduction but there is sufficient case series evidence that this ligament reconstruction is rarely necessary if the ulna is brought out to length.

“Pity the young surgeon whose first case is a fracture about the child’s elbow.” - Mercer...
Figure 11a – Lateral view of a Monteggia fracture which was missed and presented after six weeks of treatment in a cast. Note the anteriorly dislocated radial head with some heterotopic ossification in the capsular tissue around it.

Figure 11b – After ulnar osteotomy with slight overcorrection of ulnar alignment and also restoration of length. The radial head required an open reduction. The ulnar shaft is now pulling the radial shaft into its correct alignment via the interosseous membrane.

Figure 11c – The missed Monteggia fracture after healing of the ulnar osteotomy.

6. Complications of Elbow Fractures

6.1 Nerve Injury

Nerve injuries are common with displaced fractures around the child’s elbow because of the close proximity of the radial, median, and ulnar nerves to the bones. With a supracondylar fracture of the humerus, for example, the overall incidence of nerve injury is estimated at 10% to 15% (27). Careful physical examination at the time of initial evaluation will identify most of these injuries and should be objectively recorded in the chart. The vast majority of nerve injuries occurring with these fractures are neuropraxias and they will resolve spontaneously with observation. In some cases the axons have been damaged but the nerve trunk remains intact - this is known as an axonotmesis but it also has an excellent prognosis in childhood in that most children recover full function, although recovery may be delayed for a few weeks as new axons will grow from the point of injury to the motor point of the nerve at about 1 mm per day. An advancing Tinel’s sign can track this progress in the older cooperative child.

It is rare for a nerve injury to warrant open exploration but the cases where this might be considered include those where the nerve may be entrapped within the elbow joint, such as a post-reduction ulnar nerve injury following an elbow dislocation, for example.

6.2 Vascular Injury

An extension type supracondylar fracture pulls the brachial artery and median nerve against the sharp end of the proximal fracture fragment. The artery may be contused, stretched, or lacerated. At initial evaluation an absent radial pulse is highly predictive of a vessel injury (Mehlmann). The initial step in management is always prompt closed reduction and stabilization of the fracture, followed by re-evaluation of the vascular status. Often the radial pulse will return, and the hand will be warm with other evidence of perfusion including skin and nail bed capillary refill, muscle power, and skin sensation. Sometimes the radial pulse will not return, but the other signs show that the hand remains perfused. If the clinical findings indicate that the hand remains perfused, then it is not necessary to expose the brachial artery or attempt to repair it. Even if the forearm is reliant on collateral circulation, the clinical outcome can be excellent. On the other hand, if the hand is cold and pale with no signs of circulation, then exploration and repair of the brachial vessel is warranted to prevent ischemic necrosis of the distal part of the limb. Fortunately this latter circumstance is rare in
clinical practice.

**6.3 Compartment Syndrome**

Prevention: Swelling around supracondylar fractures poses a risk of compartment syndrome. Compartment syndrome is an evolving ischemic necrosis of muscle and nerve due to inadequate circulation. Once the pressure in a muscle compartment exceeds that in the veins, the venous outflow will be compromised and swelling and ischemia will increase. Both arterial and venous compromise are more likely if the swollen elbow is flexed in order to maintain a reduction which is why current authors recommend treating supracondylar fractures in a manner that avoids forced flexion - this can be pinning, traction, or casting in extension.

Some children will develop a compartment syndrome even if flexion is avoided. Children with fractures at two different levels (eg. a distal radius fracture and a supracondylar fracture) or children with injuries from high energy mechanisms (road traffic, falls from heights) are at increased risk.

Diagnosis of a compartment syndrome is clinical. Pain in the muscle out of proportion to the underlying injury is the cardinal sign. Pain on passive stretch of the involved muscle, and inability to actively move the involved muscle are important clinical findings but are often matters of degree in early presentation - so repeated examination by the same clinician is often important in determining whether a child is improving or becoming worse. Once the clinical diagnosis is made the treatment is a fasciotomy of the forearm, ideally with some form of stabilization of the fracture to allow for easier aftercare. Many fasciotomies can be closed in a delayed primary fashion within 7 to 14 days after injury, some may require skin grafting for final closure.

![Figure 12 – Compartment syndrome following fasciotomy in a child with severe elbow and forearm level fractures injuries from a motor vehicle crash.](image)

**6.4 Open Fractures**

Surgical debridement and irrigation are the most important steps in preventing infection following an open fracture. There is little evidence specific to children supporting this surgical dogma - but there is recent case series evidence in the literature questioning it. Specifically, some prospective studies have suggested that emergency department debridement of grade 1 open fractures from gunshot wounds is equally effective compared with operating room debridement in high volume trauma centers in the US (28). Some centres are advocating nonoperative management of low energy open fractures in children based on small case series (29,30). These results may not be applicable to paediatric fractures in resource constrained environments. First, it may not be possible to get as complete an irrigation and debridement without a general anaesthetic in a child. Second, penetrating trauma seen in adults often involves clean implements including bullets and knives, and cleaner urban environments. Children more often have open fractures from within out, with the bone injuring the skin and being exposed to the ground where the child fell. Third, with the elasticity of children’s tissue there may be a full plug of earth in the end of a distal humerus with an open injury that looks little larger than a pinprick once the tissues have rebounded. The conservative approach with open children’s fractures is to follow surgical dogma and perform a formal open debridement and irrigation.

**6.5 Malunion**

Malunions in the plane of the elbow can be expected to remodel while varus or valgus malunions generally do not. Within the first 7 to 14 days after an injury it may be possible to correct an impending malunion by closed manipulation and casting or pinning. After that point it is generally better to allow the bone to heal and remodel. Most malunions around the elbow are of cosmetic rather than functional significance as discussed in the section on varus malunion after supracondylar fracture above.

**7. Levels of Evidence in Paediatric Orthopaedic Trauma**

Children’s fractures are common clinical problems and yet there is little high level evidence guiding their treatment. A clinical practice guideline on treatment of paediatric supracondylar humerus fractures was recently published by the American Academy of Orthopaedic Surgeons at [http://www.aaos.org/research/guidelines/SupracondylarFracture/SupConFullGuideline.pdf](http://www.aaos.org/research/guidelines/SupracondylarFracture/SupConFullGuideline.pdf). The author of this review also served as the chairman of the guideline committee. AAOS uses an evidence based methodology which explicitly seeks and uses the highest level of evidence available to answer a specific clinical question.

For the guideline on supracondylar fractures a total of 44 clinical studies were included after identifying over 1000 studies. Among these studies there were only two designed as randomized trials, with some identified methodological flaws. Accordingly, the guideline could only make moderate or weak recommendations with the published evidence available about one of our most common and significant fractures. Many of the clinical questions in the guideline could not be answered with the available evidence and are listed as inconclusive - these included important but rare considerations such as optimal management of vascular injuries, but also common questions such as the role of supervised exercises in recovery of range of motion, and the best timing for return to activity following injury.

It is clear from the AAOS guideline that many decisions that need to be made in practice are not settled with high quality evidence – even for common, complicated fractures in high resource settings. A research priority for the orthopaedic community should be identifying and reporting the best management of children’s fractures in the resource constrained environments where many of these injuries occur. Optimal management of these common injuries can prevent substantial morbidity among children.
8. References


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