CHILDREN

Supracondylar fractures of the humerus

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Summary
Supracondylar fractures of the humerus are one of the most common fractures of childhood. With the recognised complications of cubitus varus, injury to any of the three major nerves around the elbow, absent radial pulse after fracture reduction, stiffness and the fortunately rare incidence of Volkmann’s ischaemic contracture, an appropriate understanding of the pathology and management of this frequent fracture is required. Both flexion and extension types occur, with the most common of the two being the extension injury. This article presents a review of the incidence, pathology, features and treatment options available, focusing on the extension-type fracture.

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Introduction
Supracondylar fractures of the humerus have been recognised since the time of Hippocrates and are one of the more common fractures in children. Cheng* reported it to be the second most common fracture in childhood (16.6%) and the most common before the age of seven. The fracture is a metaphyseal injury that does not involve the physis or epiphysis. The injury is analogous to other periosteal sleeve injuries and therefore is capable of being successfully managed in a variety of ways as modelling in the sagittal plane is almost always excellent.

With recognised complications of cubitus varus, injury to any of the three major nerves around the elbow, absent radial pulse after fracture reduction, stiffness and the fortunately rare incidence of Volkmann’s ischaemic contracture, it is perhaps not surprising that Gartland comment that “it is interesting to observe the trepidation with which men, otherwise versed in trauma, approach a fresh supracondylar fracture”.

Before the age of two, the “low supracondylar fracture” is an entity to beware of, as the largely unossified distal humeral chondro-epiphysis renders radiological interpretation in this age group difficult and injuries are often “missed”. The injury is usually a Salter–Harris type II equivalent. The even rarer distal humeral physeal separation is often misinterpreted as a humero-ulnar dislocation. The position of the capitellar ossific nucleus in a normal relation to the proximal radius however will dispel this misconception in those well versed in interpretation of children’s radiographs.

The importance of these injuries lies in the higher rates of growth disturbance and avascular necrosis of the trochlea encountered. The deformities arising after such injuries tend to be progressive and involve stiffening of the elbow often with pain that is initially of an inflammatory nature.
although eventually mechanical symptoms will develop. The latter may be addressed by corrective osteotomy, but if undertaken before skeletal maturity the deformity will often rapidly recur. Careful consideration to controlling the disordered growth will need to be given to such cases. Advice that the risks of long-term stiffening and the need for repeated surgery until the child has reached skeletal maturity needs to be part of the process of obtaining informed consent.

By contrast, the supracondylar fracture when malunited (particularly in malrotation) may result in an altered arc of motion but very little restriction of range of motion. The tendency in children younger than 10 is for modelling to correct sagittal plane deformity and for function to return to normal. A severe “gunstock” deformity that is for the most part caused by malunion of the distal fragment in medial rotation and on some occasions with an element of cubitus varus (the latter occurring when there has been comminution of the medial side of the metaphysis) will sometimes give rise to mechanical symptoms when the elbow is axially loaded moving from flexion into extension with posterolateral rotary instability of the elbow. This will form the basis for an objective indication for surgical correction of these deformities. Where function is normal but surgery is requested for cosmesis, careful explanation of the risks associated with periartricular osteotomy need to form part of the process of obtaining informed consent.

After age 15, it is a rare fracture, distal humeral fractures tending to be of a more adult pattern, frequently involving the articular surfaces and extending proximally into the diaphysis.

Incidence

Age is the key factor in the incidence of supracondylar fractures, occurring almost exclusively in the immature skeleton between the ages of two and ten.7,8 Incidence increases during the first 5 years and peaks at age 5–8, decreasing after until age 15.

Fahey9 noted that older children have a greater displacement in their fracture pattern, findings that were mirrored in the series of 800 reported by Henrikson.10 Factors such as handedness, nerve injuries and flexion versus extension injuries have been reported in various series. The incidence of these factors has been summarised from data from 61 series, totalling 7212 fractures.11

Average age was 6.7 years with the left side predominating (60.8%). The fracture occurs mostly in boys (62.8%) with an open injury occurring in 1% of cases. Nerve injuries occurred in 7.7% of fractures, with the radial most commonly affected (41.2%), followed by the median (36.0%) and the ulnar (22.8%). Following the report of Spinner12 and more recent series,13,14 injury to the anterior interosseous either in isolation or combination has been reported as the most commonly involved nerve. With absent sensory and minimal initial motor deficit careful assessment is required to detect compromise.

True Volkman’s ischaemic contracture remains a fortunately rare complication being described in the combined series in 0.5% of cases. The precise aetiology of this contracture is often debated. When seen, it is often a slowly evolving contracture due to progressive fibrosis of the muscles in the flexor compartment of the forearm presumed to be due to ischaemia secondary to arterial injury or compartment syndrome. Treatment can be by passive stretch and splintage to prevent progression with surgical release if required. Unfortunately, functional recovery is usually poor.

Pathology

Flexion-type fractures are rare with a reported incidence of 2%.11 It occurs classically with the patient falling directly onto the posterior part of the elbow, producing an angulation of the distal fragment seen on the lateral X-ray the reverse of that seen in the commoner extension-type injury. With complete displacement the distal fragment tends to migrate proximally.

With the peak incidence of supracondylar fractures occurring towards the end of the first decade, there has to be an association with the anatomy of the elbow at this period of growth that accounts for this. The three major factors would appear to be bony architecture, ligamentous laxity and the position of the joint in hyperextension. During the age period for supracondylar fractures, the metaphysis is undergoing a period of remodelling, which decreases both the anteroposterior and lateral diameters. The newly formed trabeculae and cortex are thinner, and this is found maximally at the olecranon fossa. Ligamentous laxity with hyperextension is normal in children. Thus, the elbow is more likely to be hyperextended at the time of the fall. With the extension of the elbow, the linear force acting along the extended elbow is converted to a bending force. The elastic epiphyseal and articular cartilage of the distal segment act to transfer this force to the supracondylar area. With the anterior capsule and anterior portion of the collateral ligaments tight in hyperextension and the bony olecranon concentrating the force around the fossa, fracture can occur when the forces exceed the strength of the bone to resist them. The mechanism of hyperextension leading to fracture has been supported in two cadaveric studies.15,16

Classification

Extension fractures have been classified many times. Currently, the two generally recognised classifications are those of Gartland6 and the subsequent modification of Wilkins.17 Gartland’s original classification involved three types:

- **Type 1**: Undisplaced.
- **Type 2**: Displaced with intact posterior cortex.
- **Type 3**: Displaced, no cortical contact posteromedial or posterolateral.

This was subsequently modified by Wilkins:

- **Type 1**: Undisplaced fracture.
- **Type 2A**: Intact posterior cortex and angulation only.
- **Type 2B**: Intact posterior cortex, angulation and rotation.
- **Type 3A**: Displaced, no cortical contact, posteromedial.
- **Type 3B**: Displaced, no cortical contact, posterolateral.
Clinical signs, symptoms and assessment

As with any injury an appropriate and adequate history and examination are mandatory. It is helpful if possible to establish the mechanism of injury as well as the point of maximal tenderness and timing of pain. Development of forearm pain some hours after the injury may indicate muscle ischaemia.

The most important part of the clinical exam is to establish and document the integrity of the neuro-vascular structures. Subsequent changes in status are more readily assessed if a thorough initial assessment is available for comparison. Each of the major nerves must be assessed for both motor and sensory function, being especially careful to assess the anterior interosseous nerve. This is the last major motor branch of the median nerve, innervating Flexor Digitorum Profundus to the index and middle fingers as well as Flexor Pollicis Longus and Pronator Quadratus. With injury, clinical loss of interphalangeal joint flexion of the thumb and the distal interphalangeal joint of the index finger can be demonstrated. Patients are unable to make an “OK” with tip-to-tip pinch, substituting with side to side pinch (OK sign/Kiloh–Nevin sign).

Vascular assessment is vital and can be considered as a static and dynamic review. Static assessment involves evaluation of the peripheral pulses and capillary filling. Absence of a pulse is a matter of concern, however, there may be adequate supply without a palpable radial pulse.18–22 Use of hand-held Doppler, if available, can be helpful in these circumstances. Dynamic assessment involves the review of the function of the dynamic structures (i.e. muscles) and the adequacy of their vascular supply. Forearm versus localised elbow pain, lack of voluntary finger extension and forearm pain on passive extension are all clinical alarms of vascular insufficiency in the forearm.

S-shaped deformity

With completely displaced Type 3 fractures, the limb develops two points of angulation to give it an S-shaped position. In the distal arm, there is an anterior prominence that overlies the distal end of the proximal fragment. The distal fragment is displaced proximally with the posterior olecranon becoming more prominent. Finally, as the distal fragment is flexed at the elbow, there is an anterior concavity accentuating the S-shaped deformity.

“Pucker” sign

If one of the spikes from the proximal fragment penetrates the dermal layer, there may be a puckering of the skin. This “pucker sign” is an alert to the fact that the fracture may be difficult to reduce by closed manipulation or traction.

Rotation producing angulation

With the fracture there may also be rotation of the elbow and forearm, as well as angulation at the elbow. Normally, the forearm follows the distal fragment and tends to lie in internal rotation. This is especially true if the medial spike of the proximal fragment is anterior to the distal fragment. The rotation of the distal fragment can thus be associated with a subsequent medial tilting of the distal fragment, accounting for the varus angulation. With a posterolateral distal fragment and the lateral spike of the proximal fragment anterior the opposite can occur. The forearm and elbow may be externally rotated with valgus angulation at the elbow. This is less common.

X-ray findings

Interpretation of children’s elbow X-rays is a potential trap for the uninitiated. Appreciation of what is normal, especially with respect to ossification timings of the epiphyses is vital. The standard X-rays required are an anteroposterior view with the elbow extended and a lateral view with the elbow flexed to 90° and the forearm in neutral. In the injured child, obtaining these views can be difficult. With a high index of suspicion of fracture, but none apparent on these views, subsequent oblique views may be helpful.

On the anteroposterior view, the main landmark is the angulation of the physeal line between the lateral condyle and the distal humeral metaphysis. This physeal line forms an angle with the long axis of the humerus termed Baumann’s angle (Fig. 1). The mean angle is 72° (64–81°),23 and is consistent when both sides are compared and the X-ray beam is directed perpendicular to the long axis of the humerus.

On the lateral X-ray, the teardrop is visible in the distal humerus (Fig. 2A). This consists of the anterior line representing the posterior margin of the coronoid fossa and the posterior line representing the anterior margin of the olecranon fossa. The inferior portion is the ossification centre of the capitellum. The “shaft-condylar angle” represents the angulation between the long axis of the humerus and the lateral condyle and is normally 40° (Fig. 2C). If a line is drawn along the anterior border of the distal humeral shaft it should pass through the middle-third of the ossification centre of the capitellum, termed the “anterior humeral line” (Fig. 2B). Posterior displacement of the ossification centre of the capitellum in relation to the
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Figure 2  (A) (i) Teardrop sign. (B) (ii) Anterior humeral line. (C) (iii) Shaft-condylar angle.

The anterior humeral line is of value in minimal hyperextension of the distal fragment.

There are three fat pads overlying major structures in the elbow: the posterior (olecranon), anterior (coronoid) and the supinator. Displacement of any of these may indicate an occult fracture. It is worth noting that the capsule must be intact for displacement to occur. In Corbett’s review of elbow injuries displacement of the posterior fat pad was almost always associated with fracture, whereas displacement of the anterior fat pad alone could occur without fracture. The fat pad is best visualised on the true lateral view X-ray; however, this may be difficult to obtain in the acute situation.

Treatment of extension fractures

We will concentrate on the treatment of the much more common extension fracture. Before we decide on what treatment should be performed, it is important to first understand the effect of various deformities. Mann reviewed 23 patients that had been treated with manipulation, 15 of whom had residual deformity at follow-up greater than 2 years. Posterior, medial and lateral displacement was found to remodel without problems. Posterior angulation was not found to leave any great residual hyperextension. In this and other series medial rotation in conjunction with angulation was found to predispose to cubitus varus.

With Type I fractures some authors such as Piggot would treat patients merely with a collar and cuff for 3 weeks. In our institution, we prefer to place patients in a light weight above elbow cast for 3 weeks, before allowing patients to freely mobilise thereafter.

In Type II fractures where the posterior cortex is intact, Wilkins suggested that as the posterior cortex is intact they could be safely manipulated and held in flexion with a figure of eight cast. Other authors have advocated manipulation, with or without pinning, while some prefer traction. Type II B fractures in particular, with their rotational component (usually medial) are more likely to require some form of formal stabilisation as for Gartland III injuries. Several authors have noted that the use of manipulation with plaster alone for Type II and III injuries lead to a 60% rate of redisplacement. Again such injuries often occur in the presence of very severe swelling and the more stable position of the fracture in deep flexion can cause vascular compromise, McLaughlin’s “supracondylar dilemma”. In their studies, Abraham and Khare showed that immobilising the elbow in pronation was more stable for all types of supracondylar fractures.

Traction

Traction can be skeletal with either a wire or a screw. Palmer et al. in their series produced good results with a winged screw inserted in the ulna and overhead skeletal traction. There were no cases of iatrogenic nerve damage, or Volkman’s contracture. Indeed, within 2 days the pulse returned in two patients that initially had no radial pulse. There were though two cases (out of 32), of soft tissue infection that required incision and drainage. First described by Dunlop, various authors have since advocated the use of straight arm skin traction. They were able to produced predominantly good or excellent functional results, with only a few cases of cubitus varus, and no iatrogenic nerve palsies.

In our institution after reviewing our results, all patients under the age of 10 with closed, isolated supracondylar distal humeral fractures and no vascular compromise are treated with straight arm skin traction. Skin traction is applied with the elbow extended and the forearm supinated and in the straight lateral position. Adhesive tapes are applied to the forearm and held with an elasticated bandage with the shoulder at 90° of abduction. The cord is passed through a universal pulley and enough weight applied (usually 0.45–1.8 kg) so that the arm is just lifted from the surface of the bed (Fig. 3). A single dose of opiate is all that is required prior to application of traction. The traction side of the bed is elevated to provide counter traction. Neurovascular status is closely observed and weekly X-rays are taken. The position of the traction can be adjusted so that the carrying angle can match the uninjured limb. Traction is discontinued when the patient can actively flex the elbow.

Although the results from straight arm traction are equivalent to many series using pinning, it is not without its drawbacks. Traction relies on remodelling for patients to regain their full range of motion (Fig. 4) (which on average in our series was 24 months). The prolonged hospital stay can be a burden for parents of up to 4 weeks. Prietto compared the results of straight arm traction with percutaneous pinning. The results of his patients in traction were much poorer than other studies, with a 33% rate of cubitus varus! He did also note that traction led to a considerably longer stay, (17.5 days, compared with 2.7 days for pinning). Costs were also considerably greater, with traction costing 79% more at the time of this study in 1979.

Even if traction is not being used as the definitive treatment, it can be used to immobilise the limb comfortably prior to surgery and allow the soft tissues to settle.
Reduction of fracture

Prior to consideration for pinning of any supracondylar fracture, an adequate reduction should be performed under general anaesthetic. With image intensifier assistance and the arm extended, or hyperextended and supinated, longitudinal traction should be applied. With the traction maintained, medial or lateral displacement can be corrected with a valgus or varus force. Once length has been re-established the elbow should be flexed with posterior force on the proximal fragment and anterior force on the distal fragment. It is important that repeated attempts at reduction are not made as this can lead to poorer results. Should there be any puckering of the skin prior to, or during reduction soft tissue may be entrapped within the fracture site. Further traction tightens the soft tissues, preventing reduction. In such cases, manipulation with a massaging action may lift the soft tissues off the metaphyseal fragment and allow reduction, otherwise open reduction is indicated.

k-Wires

Wires of at least 1.6–2 mm thickness should be used depending on the size of the patient. Biomechanical studies have suggested that cross k-wires are more stable than two lateral wires. It is also suggested that the use of two lateral wires would reduce the risk of iatrogenic ulnar nerve injury. Recent clinical studies have not borne this out and produced excellent and comparable results with both two lateral pins and crossed k-wires with no differences in terms of loss of position. If inserting a medial wire, it is important to ensure that the ulnar nerve has not subluxed forward. This can be done by extending the elbow to less than 90° (typically 50–70°), after the lateral wire has been inserted and/or using a mini open procedure. Wilkins though has suggested that the medial wire should be placed first in the presence of the more common posteromedial fracture so as to provide a buttress, as the comminution is on this medial side in this pattern of fracture. Lateral K-wires should be divergent and enter the medial cortex, but not go through too far as to injure the ulnar nerve (Fig. 5). They should also be greater than

Figure 3 A clinical photograph demonstrating the techniques of straight arm traction.

Figure 4 Serial X-rays demonstrating remodelling of a Gartland 3 supracondylar fracture.
Although parallel wires have been advocated, the more medial of the two would then be intra-articular. If a crossed wire configuration is to be used, the wires must cross above the level of the fracture site and enter the opposite cortex (Fig. 6).

The decision on whether or not to bury the wires is made by balancing the reduction of infection against the risk of a further general anaesthetic. Mazda et al. had no infections when they buried their wires. Iobst et al. from Miami were able to have no infections despite using what they referred to as a semi-sterile technique for their percutaneous pinning, this was both with and without peri-operative antibiotics. They also reviewed the literature between 1974 and 2004 and found a superficial infection rate of 2.3%, which could be treated with antibiotics, while 0.5% required more than just antibiotic treatment.

One thing in common amongst these most recently published studies is that better results are obtained when the surgeons involved are experienced in paediatric orthopaedic surgery or experienced trainees.

Open surgery

Indications for open surgery are open fracture, failure to achieve an adequate closed reduction, or vascular compromise. Blount and Lipscomb suggested that the absence of a radial pulse in the presence of a warm hand with good circulation in itself is not an indication for exploration and should be treated expectantly. For other cases, if there is no return of circulation once the fracture has been reduced an exploration should be performed.

If an open approach is required it should be done with a tourniquet in place, but not through a posterior approach. This approach does not give access to the neurovascular structures most likely to be damaged and will disrupt the tissues that are most likely to be uninjured. Various authors have also suggested that the posterior approach pre-disposes to post-operative stiffness.

A medial or antero-medial approach would allow access to the most commonly injured structures, visualisation of the ulnar nerve and allow access to the area of comminution, and the area that tends to be displaced when the fracture rotates.

Physiotherapy

Keppler et al. in comparing two groups of patients, only one of which had physiotherapy showed that although the range of motion was better at the 12- and 18-week stages post-operatively, there was no difference at 1 year between the two groups. They therefore felt that therapy was unnecessary.

Correcting cubitus varus

Labele et al. suggested caution in the treatment of cubitus varus, finding no differences in function between patients that had correction and those that did not, stating that treatment was purely cosmetic. Others have suggested an increased risk of cubitus varus and impairment in throwing athletes.

There is a lack of remodelling potential in the coronal plane, particularly in the older child. For this reason, observation is of little benefit in cubitus varus. The medial epiphysiolysis is also of no benefit in cubitus varus leaving only osteotomy in those that require intervention.

The three most popular corrective osteotomies are the lateral closing wedge, the step cut lateral closing wedge and the dome rotational osteotomy. Although the lateral closing wedge is technically safe and simple, the scar can become hypertrophic, there can be difficulty achieving fixation and there is a prominence of the lateral condyle which may compromise the final cosmetic outcome. Ippolito reported 50% poor results associated with loss of correction and recurrent deformity.

DeRosa and Graziano described an interlocking stepcut lateral closing wedge with fixation with wires or a single screw. This stepwise cut provided extra stability and mainly good or excellent results. The fragment can only rotate in the horizontal plane and can provide only limited medial and lateral translation of the distal fragment.

A dome osteotomy can produce correction in both the horizontal and coronal planes, although rotation may be limited by the medial soft tissue. A medial opening wedge osteotomy will maintain humeral length and does not produce a translational deformity. It does, however, take
longer to heal therefore requiring longer immobilisation and there is also a risk of ulnar nerve neurapraxia.⁶⁰

**Treatment of flexion fractures**

When undisplaced, flexion injuries can be treated by simple immobilisation. Once displaced such injuries should be treated with wire fixation. Although this can be achieved closed, some will require open fixation. This can be ideally done through a medial approach.²⁸

**Conclusion**

Supracondylar fractures of the distal humerus may represent a very significant injury. Unstable fractures can be treated with either traction or k-wiring with satisfactory results if done well. If wiring an appropriately trained surgeon should at least be present, a satisfactory reduction achieved and careful wire insertion performed to reduce the risk of iatrogenic injury.

**References**

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