Staying out of trouble with paediatric supracondylar fractures

A review of pitfalls and controversies

Supracondylar fractures most commonly occur in children aged between five and seven years,[1] and are usually the result of accidental trauma rather than non-accidental injury, although the latter should be considered in children under 18 months old.[2]

The majority (~98%) are extension-type,[1] with relative posterior displacement of the distal fragment and the proximal fragment pressing into the tissues anteriorly (Fig. 1). Extension-type supracondylar fractures are commonly classified by Wilkin's modification of the Gartland classification, which can also be used to guide management.[3] Close review of the radiographs preoperatively is essential, as poor radiographs, incomplete ossification, and soft-tissue swelling are common and can cloud the picture. Extension-type fractures can be divided into posteromedial (75%) and posterolateral (25%) subtypes;[4] posterolateral displacement has an increased risk of median nerve and brachial artery injury, and entrapment of these structures in the fracture site must be considered if there is difficulty in reducing posterolateral fractures. Flexion-type supracondylar fractures account for around 2% of supracondylar fractures and result from direct trauma with the elbow joint in flexion, or a fall onto a flexed elbow.[1] Flexion-type fractures can often be picked up by a careful review of the mechanism of injury and detailed review of the preoperative radiograph. A clue may be the lack of an oblique line distal-anterior to proximal-posterior on the lateral radiograph. It is essential to try to identify these injuries preoperatively to allow better preoperative planning, as flexion-type fractures are often more technically challenging to reduce (the reduction technique is in extension rather than in flexion) and have an increased rate of open reduction.[5]

WHICH FRACTURES REQUIRE FIXATION?

Undisplaced (Gartland type 1) fractures are almost universally treated conservatively. However, it is important to study the antero-

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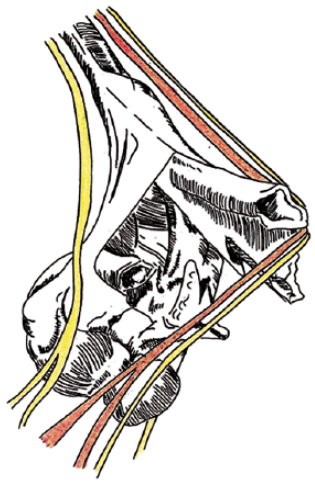

Fig. 1 Pathoanatomy of a posterolaterally displaced Gartland III extension-type supracondylar fracture. Illustration courtesy of Mr A. Faulkner.

posterior radiograph carefully for any signs of varus or valgus impaction (indicative of a grade 2 injury). Clinical comparison of the carrying angle of the contralateral elbow is very useful in assessing coronal plane malalignment. Above-elbow back slabs have been shown to provide superior pain-relief to collar and cuff immobilization.[6,7]

Gartland grade 2 fractures are usually divided into grade 2a, in which the distal fragment is posteriorly angulated, and grade 2b, in which the distal fragment is both angulated and rotated. For stability without Kirschner wire (K-wire) stabilization, $>120°$ of elbow flexion is recommended to minimize the risk of displacement.[8] However, hyperflexion of the elbow has been shown to predispose to increased compartmental pressures,[9] and therefore most centres now routinely K-wire all type 2 fractures.

All Gartland grade 3 fractures should be stabilized as these are unstable injuries, and conservative management is associated with complications and a poorer functional outcome.

WHEN SHOULD THE FRACTURE BE TREATED?

Traditionally, displaced supracondylar fractures were treated in an emergency manner due to risk of neurovascular injury, but there have now been multiple studies that have reported safe, delayed management of supracondylar fractures, with no effect on rate of open reduction, operating time, length of hospital stay, or complication rates.[10-15] However, a multicentre paper reported 11 cases of compartment syndrome developing among children who had presented with low-energy injuries and an intact radial pulse. The authors questioned if the pendulum has swung too far towards delayed surgery, thereby putting some patients at risk of secondary compartment syndrome.[16] This has re-emphasized the need for close monitoring of these patients, and the individual nature of each case must be considered to ensure that children with absolute indications for emergency surgery (Table I)[17] are identified early. Additionally, fractures with posterolateral displacement of the distal fragment should be considered for urgent fixation, as these injuries place the median nerve and brachial artery at increased risk; therefore, careful evaluation of these patients is essential if surgery is to be delayed.[18] Fractures with median nerve involvement will need careful monitoring as the paraesthesia may mask the pain of incipient compartment syndrome.

Table I. Indications for emergency treatment of supracondylar fractures

Indication
Absent radial pulse
Skin compromise
Compartment syndrome
Open contaminated fracture

HOW SHOULD THE FRACTURE BE FIXED?

How should the wires be configured?

Controversy remains regarding optimal wire configuration, with the complications driving the debate being risk of iatrogenic nerve injury and loss of stability of the fixation construct.

Traditional fixation has involved crossed-wire fixation, i.e. one medially placed wire and one laterally placed wire. The problem with this method is the risk of iatrogenic ulnar nerve injury with the placement of the medial K-wire. While proponents argue there is little in the way of increased risk, there are multiple studies showing higher rates of iatrogenic ulnar nerve injury using the crossed-wire technique.[19] A systematic review in 2010 reported that crossed pinning results in one extra nerve injury for every 28 patients treated, compared with lateral-only pinning.[19] Iatrogenic injury of the ulnar nerve may occur via direct-wire penetration or, more commonly, through narrowing of the cubital tunnel. To reduce the rate of iatrogenic ulnar nerve injury with medial wire placement (the ulnar nerve is extremely mobile in children and may not be exactly where expected),[20] current British Orthopaedic Association (BOA) guidance advocates that "techniques to avoid ulnar nerve injury should be employed".[21] We recommend a mini-open technique to assist with placement of the medial wire.

An alternative is placement of two or three lateral wires, the 'lateral-only' method. Lateral wire configurations help to overcome risk of injury to the ulnar nerve, although cadaveric studies have shown inferior mechanical stability.[22-24] However, other studies have failed to replicate these findings, reporting comparable biomechanical stability.[25-27] The most recent meta-analysis (2016) comparing crossed-wire fixation to lateral-only fixation included 13 studies (seven randomized controlled trials and six prospective comparative cohorts) and reported that the rate of iatrogenic ulnar nerve injury was 4.1% in the crossed-pin group *versus* 0.3% in the lateral-only group, and reported no difference in terms of radiographic outcomes, function, or other surgical complications between the two groups.[28]

Despite the higher risk of iatrogenic nerve injury with use of a medial K-wire, there remains a risk of iatrogenic nerve injury with all methods of fixation, emphasizing the importance of a detailed preoperative neurovascular assessment. Surgeon familiarity and experience is likely to be the main determining factor in the wire configuration used and success of treatment, with each method having advantages and disadvantages. We would advocate live screening following

Table II. Key British Orthopaedic Association (BOA) technical recommendations for surgery on paediatric supracondylar fractures

Recommendation
Surgical stabilization should be with bicortical Kirschner wires (K-wires)
If a medial wire is used, "techniques to avoid ulnar nerve injury" should be used and documented in the operation note
2 mm wires should be used if possible
A perfused limb does not require brachial artery exploration whether or not the radial pulse is present

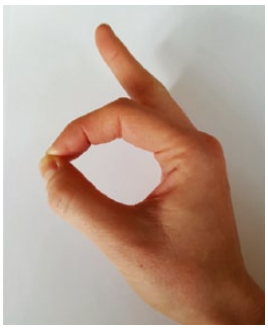

Fig. 2a

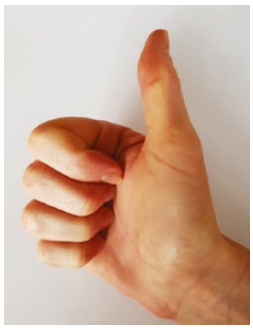

Fig. 2b

Fig. 2c

Assessing hand neurological supply in children. a) Testing the anterior interosseous nerve (AIN): ask the child to make an 'OK' sign, which indicates integrity of the index finger flexor digitorum profundus (FDP) and the flexor pollicis longus (FPL). This requires the child to flex his or her interphalangeal joints (IPJs). b) Testing radial motor function: ask the child to give a 'thumbs up' sign, which tests the extensor pollicis longus. c) Testing ulnar motor function: ask the child to make a starfish sign, which tests the finger abductors.

fixation with a lateral-only technique and the use of a medial wire if the fixation appears unstable. In very young children, it can be technically challenging to use lateral-only wires and medial wires may be needed. Larger K-wires have been shown to provide superior biomechanical stability and therefore the BOA advise that 2 mm wires should be used, if possible (Table II).[22] However, in practice, 1.6 mm K-wires need to be used for smaller children, including most under six years of age.

How do you recognize and avoid nerve injury?

Neurological injury, most commonly a transient neuropraxia, is apparent in 11.3% of displaced supracondylar fractures.[29] Injury of the median nerve is the most common neurological injury – this often presents as an anterior interosseous nerve (AIN) palsy but the pathoanatomy is an injury to the fasicles of the AIN within the median nerve (the AIN fascicles are located at the dorsal aspect of the median nerve prior to emerging as the AIN distal to the elbow).[30,31] Nerve injuries may result from traction, direct trauma, or ischaemia of nerves.[32,33]

Preoperative documentation of neurovascular status in supracondylar fractures is often poor, particularly of the AIN.[34,35] Documentation may be lacking because neurovascular assessment can be difficult due to pain and anxiety or age of these patients. In addition to this, a lack of familiarity of the junior medical team to assess these nerves can be a problem. With the changes in on-call patterns and the introduction of 'hospital at night' in many institutions, junior doctors unfamiliar with musculoskeletal and neurological examination are often asked to care for these patients during out-of-hours periods. Davidson[36] described assessment of neurological function using the 'rock, paper, scissors' game. The median nerve flexes the wrist and fingers into a rock, the radial nerve extends the fingers to make paper and the ulnar nerve claws the ring and little finger during scissors, as well as abducting the index and middle finger.[37] Another method, as shown in Figure 2, is to ask the child to give thumbs up (radial nerve), make the 'OK' sign (AIN), and make a starfish sign (ulnar nerve). It is crucial that findings are well documented to identify patients requiring urgent intervention and to allow changes in neurovascular status to be monitored over time. In very young or uncooperative patients, the tactile adherence test can also be extremely useful: when a ballpoint pen is lightly drawn across the skin, there is loss of friction due to loss of tactile adherence in an anhidrotic area resulting from autonomic nerve dysfunction.[38] Ultimately, it is the responsibility of the operating surgeon to ensure that an accurate neurovascular examination has been undertaken and recorded, and we advocate recording preoperative neurovascular status on the operation note.

Reassuringly, outcomes following nerve injury in supracondylar fractures (even iatrogenic) are generally good, as the majority are neuropraxias and usually recover spontaneously within three to six months.[39-41] If the nerve has not recovered by three months, nerve conduction studies should be arranged and the case discussed with the local peripheral nerve unit.

What do you do with the pink pulseless hand?

Up to 20% of displaced supracondylar fractures present with an absent pulse.[42] Vascular complications are usually caused by injury to the brachial artery, which can suffer a broad range of complications ranging from simple vascular spasm, to intimal tear, interruption through kinking, or direct laceration.[43] Patients with an absent pulse and cool, white hand require urgent fracture reduction and restoration of the circulation.[41] BOA guidance recommends that children presenting with an ischaemic limb should be discussed with the vascular team prior to operative reduction.[26] In cases of ischaemia, reduction of the fracture often restores the vascular supply; therefore, fracture reduction should not be delayed whilst waiting for angiography studies.[44] In cases where fracture reduction does not result in spontaneous return of perfusion, urgent surgical exploration of the brachial artery should be undertaken. Symptoms of complete median nerve dysfunction in conjunction with an absent pulse have been shown to be a strong predictor of nerve and vessel entrapment, and this is an indication for urgent surgical exploration.[45]

The pink, pulseless hand is a more common presentation and causes much debate. These are often not treated as an emergency, with most surgeons opting to rely on the presumption that the collateral blood supply is sufficient to maintain circulation.[46] However, a systematic

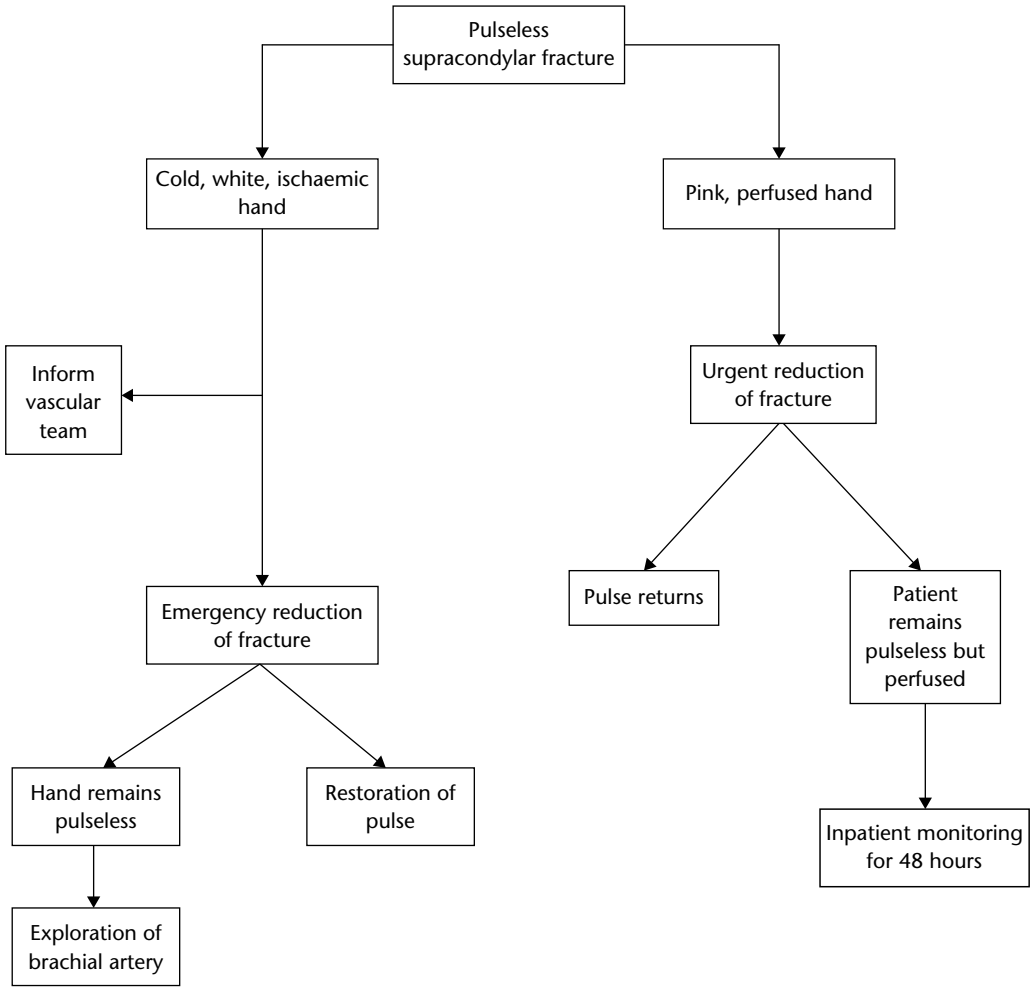

Fig. 3 Management of pulseless supracondylar fractures

review in 2010 that included 331 cases of pulseless supracondylar fractures questions this common practice, reporting that 70% of the pink, pulseless fractures had a documented brachial artery injury.[47] The authors state that as up to 20% of the population have some variation in the arterial anatomy of the upper arm,[37,48,49] collateral circulation cannot be relied upon with certainty. Management of pink, pulseless supracondylar fractures with no abnormal neurology remains controversial; however, urgent operative reduction and reassessment of vascular supply is increasingly advised.[50] If the pulse does not return following fracture reduction, then the use of either inpatient monitoring for 48 to 72 hours or a formal vascular exploration is somewhat controversial. If the hand is otherwise well perfused, we would advocate careful inpatient observation, watching for delayed vascular compromise.[51]

Our suggested management of pulseless supracondylar fractures is summarized in Figure 3.

SUMMARY

Supracondylar fractures remain a challenging fracture to treat, and there continues to be debate on the various controversies surrounding management. Undisplaced fractures can be managed conservatively, with the majority of surgeons electing to fix displaced fractures with either crossed or lateral-only K-wires. Crossed K-wires provide a stronger biomechanical construct, which comes at the cost of increased risk of iatrogenic ulnar nerve injury. The majority of supracondylar fractures can be treated in a semi-urgent manner with the indications for urgent treatment being vascular deficit, skin compromise, compartment syndrome, and open contaminated fractures. It is essential that all children are appropriately examined and neurovascular findings are well documented at initial presentation and preoperatively. The pink, pulseless hand remains a controversial area, with many surgeons treating these fractures in a delayed manner due to presumption of adequate collateral supply. Recent evidence questions this common assumption,[47] and these children should be treated in an urgent manner. If the pulse does not return in patients with a perfused upper limb, patients require careful inpatient monitoring for 48 to 72 hours, watching for delayed vascular compromise.

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