Elbow Trauma

SUPRACONDYLAR FRACTURES OF THE HUMERUS IN CHILDREN

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ABSTRACT

Supracondylar fractures of the humerus in children are either flexion or extension in type. Associated nerve or vascular injury is common. Fractures that remain stable after reduction can be treated with elbow flexion. If the fracture is unstable or if circulation is compromised, percutaneous pinning or traction treatment is utilized. The ischemic hand is always evaluated for brachial artery damage or for the presence of a compartment syndrome. Varus positioning should always be avoided, but other malalignments either remodel or are not of functional significance.

The management of supracondylar fractures of the humerus in children remains controversial, especially when there is associated nerve and vascular injury. Malreduction is difficult to assess radiographically, and it is important to know if the position is likely to result in a cosmetic or functional problem. Management begins by understanding the mechanism of injury.

In a supracondylar fracture of the humerus it is important to determine if the distal fragment lies anterior or posterior to the humerus. If it lies anterior, the supracondylar fracture occurred with the elbow in flexion and the fracture is stable in extension. It should therefore be treated in extension, and the long arm plaster may need to be supported by a cast or brace around the pelvis and chest. If treated in flexion, the fracture may need to be pinned percutaneously. Flexion-type supracondylar fractures have an associated risk of traction injury to the ulnar nerve which is bound down by the medial intermuscular septum proximal to the fracture and the cubital tunnel distal to the fracture.

More commonly, supracondylar fractures occur by forced elbow extension. The olecranon tip is driven forcibly into the thin bone at the distal humerus at the olecranon fossa and the bone breaks at the site of this fulcrum. The distal fragment lies posteriorly and the brachial artery is tented over the anteriorly protruding proximal fragment.

ASSOCIATED NERVE INJURY

When the medial periosteal hinge is intact, the distal fragment is displaced medialward and the radial nerve is stretched and tented over the laterally placed proximal fragment. When the lateral periosteum remains in continuity, the distal fragment is displaced laterally and the median nerve is stretched over the medially placed proximal fragment.

Nerve injuries occurred in 7% of 4520 fractures compiled from 31 major reported series. Since the medial displacement pattern is seen most commonly, 45% of the nerve injuries were of the radial nerve. One third were median nerve injuries and 23% were ulnar nerve injuries. Most of the median nerve injuries were of the anterior interosseous nerve with corresponding...
loss of flexion of the index distal interphalangeal joint and thumb interphalangeal joint. Most of the nerve injuries recover fully, although it may take 6 months to do so. Rarely, the radial nerve is transected.

**ASSOCIATED IPSILATERAL FRACTURES**

Since hyperextension of the elbow is often the result of a fall on the outstretched arm, a fracture of the distal radius may be seen simultaneously with supracondylar fractures. Radiographs of the forearm and wrist should be taken in the patient with a supracondylar fracture.

**ASSOCIATED VASCULAR ISCHEMIA**

Although actual discontinuity of the brachial artery can occur, more commonly the artery is in transient spasm. Occasionally an intimal tear of the artery followed by thrombosis occurs. Loss of the radial arterial pulse in the absence of other worrisome observations is of little significance. Often the patient presents with the arm splinted in full extension and the brachial artery is tented over the anteriorly protruding proximal fragment. Merely flexing the extremity 20° restores circulation and pulse. The presence of warm, pink, and non-swollen fingers with intact forearm flexor and extensor function is more important than the presence or absence of a radial pulse.

Flexion of a swollen elbow can obstruct venous return or even impede arterial flow, resulting in forearm ischemia, myonecrosis, nerve dysfunction, and further swelling. A vicious cycle may be established in which swelling within the closed muscle compartment can lead to additional ischemia and additional swelling. Fingers in this setting are swollen, cool, have sluggish capillary refill, and have altered sensation. These children have worsening pin, will not actively flex or extend the fingers, and have pain in the volar forearm with passive extension of the digits.

Compartment pressures greater than 30 mm Hg absolute are worrisome, and pressures greater than 50 mm Hg or 20 mm greater than diastolic should provoke prompt fasciotomy. Decompression of the volar forearm compartment should extend through the carpal canal into the palm and should include division of the lacertus fibrosis at the elbow. The extensor compartment also may need to be released. Decompression should be performed within 4 hours of the first signs of ischemia; otherwise, irreversible fibrosis of the involved muscles may occur. Untreated cases or cases treated too late may result in Volkmann’s ischemic contracture, but this complication is seen in less than 5% of cases.

**TREATMENT**

The associated injuries emphasize the need to treat the soft tissues of this fracture first and the bony injuries secondarily. An argument can be made that prompt treatment and stabilization of the bony injury may facilitate care of the soft tissue injury, but surgery must be appropriately timed and adequate fracture stability obtained or damage to the soft tissues can be compounded. An algorithm is presented in Figure 1 which has been used successfully at Royal Children’s Hospital, Melbourne, Australia, to the credit of Malcolm Menelaus, providing a logical, stepwise approach to the treatment of these injuries.

When the patient is seen soon after the injury and there is minimal swelling, the patient can be taken promptly to the anesthesia suite and reduced by closed manipulation. Longitudinal traction is applied with humeral counter traction by the assistant. Varus and valgus is corrected and the elbow is lifted forward and flexed. The olecranon is pushed anteriorly to reduce the posterior displacement and to restore the normal flexed position of the distal fragment. In the 5 to 7-year-old child with thick periosteum and in the older child with a stable fracture configuration, the reduction is often stable and no internal fixation is required.

The elbow is flexed to the degree that soft tissue will allow, without compromising circulation and without loss of radial pulse. A 3 inch tape is placed obliquely across the medial and lateral side of the elbow to maintain flexion, leaving the soft tissues free for expansion. A 2 inch stockinette is wrapped around the wrist to form a cuff and looped around the neck with a
foam or felt pad inside to form a collar. The arm is held against the chest with a swathe or burn stockinette (Fig 2). The wrist and hand are free for monitoring color, temperature, capillary refill, movement, and pulses. The patient is observed in the hospital overnight, and if circulation becomes compromised, the elbow can be retaped in a less flexed posture. If reduction is lost, the patient can be placed in traction and remanipulated when the swelling has diminished. Alternatively, traction could be continued until the fracture becomes immobile and a long arm plaster can be applied. Supracondylar fractures become sticky in about 5 to 7 days and should be radiographed within a week of reduction so that they can be remanipulated if position is lost.

Fractures of unstable pattern, fractures in older children with thinner periosteum, and fractures in which reduction is lost while obtaining radiographs will require percutaneous pinning for maintenance of reduction.\textsuperscript{10,11} Percutaneous pinning offers the advantage, in the swollen elbow, of treating the patient in 45° of flexion with a posterior splint, allowing no compromise of circulation by flexion. Fractures with swelling massive enough that flexion is not sufficient to achieve stability without compromising circulation also will require percutaneous pinning.

Traction has traditionally been the mainstay of treatment.\textsuperscript{12-15} It is safe because swelling is allowed and arterial or venous obstruction is avoided.\textsuperscript{16} The arm can be elevated. It safely reduces the fracture, negates the effect of rotation, reestablishes circulation, allows constant observation, allows for dependent drainage by elevation, allows early elbow motion, and allows minor manipulations if needed. It can be used in conjunction with a short arm cast for a concomitant forearm fracture.

Traction may be the only treatment possible for the massively swollen extremity. It is advised for the child with swelling referred hours after the injury, especially if repeated attempts at reduction were made previously. Traction is also useful for the child whose fracture cannot be acceptably reduced under anesthesia and in whom open reduction is not preferred or recommended.

Sidearm or overhead traction may be applied by skin or skeletal pin. The pin should be inserted from the medial side 2.5 cm distal to the olecranon tip with care taken to avoid the ulnar nerve. Traction applied to a pin placed distal to the coronoid will extend the elbow.

After swelling has resolved, the patient can be taken out of plaster, re-manipulated, and percutaneously pinned while under an anesthetic. Alternatively, the patient may be left in traction an additional week while radiographs confirm adequacy of reduction. Periosteal reaction is seen in about 10 days and a long arm plaster can be applied safely after pin removal at that time.

Open reduction with K-wire internal fixation should be performed for the open fracture requiring debridement and irrigation, in cases where the brachial artery must be repaired, in cases where the circulation or nerve function is lost after manipulation, or when the proximal fragment is buttonholed through the brachialis.

Some surgeons advocate open reduction for the fracture that is resistant to acceptable closed reduction. Caution is advised in this setting, as poor results in most series are related to open reduction. These include stiff elbow, myositis ossificans, ischemic growth plate damage, and infection. Supracondylar fractures should not be opened to achieve perfect anatomic reduction, to explore a nerve injury sustained at the time of a closed fracture, nor to evacuate a hematoma. Open reduction can be performed from a medial approach,\textsuperscript{17} lateral approach, combined medial and lateral approach, or a posterior approach.

If the fracture cannot be reduced acceptably and varus cannot be corrected, it is acceptable to treat the elbow in full extension in a plaster cast after swelling has subsided. The carrying angle is visually corrected with proper positioning. Posterior displacement and posterior tilt are inevitable, but remodel slowly with time.\textsuperscript{18-20}

Percutaneous pinning of a fracture after closed reduction has grown in popularity over
Fig 3: Treatment of supracondylar fracture with absent radial pulse.

the last decade and most surgeons now perform this routinely. The advantage is that the position of the fragments in reduction is rarely lost, and the fracture can be treated without elbow flexion.

Many techniques have been advocated, including two crossed pins, one lateral pin, two lateral pins, one vertical pin, and one lateral plus one vertical pin. If the medul epicondyce can be localized reliably, a medially placed pin crossed by a second laterally placed pin will permit the most stable fixation. Percutaneous pinning first requires a good closed reduction. Smooth pins are used, and may either be left protruding or can be bent and cut off just under the skin. Ulnar nerve injury can be avoided by pressing out edema over the medial epicondyce, incising and spreading prior to pin placement, or using a lateral and vertical pin. The vertical pin is placed adjacent to the lateral olecranon in line with the shaft of the humerus. The advantage of this latter technique is total avoidance of the ulnar nerve, but the vertical pin traverses the articular surface and rotation about the two lateral pins has been observed.

TREATMENT OF FRACTURES WITH VASCULAR INJURY

Treatment of supracondylar fractures with loss of radial arterial pulse should begin with reduction of the bone fragments by one of the methods described, preferably followed by percutaneous pinning. Even if pulse does not return, the patient needs only observation when the fingers are pink and warm with good capillary refill, good movement, and no pain with passive stretch (Fig 3). An ischemic hand, however, must be evaluated and treated. If the hand is pale, cool, and has poor capillary refill, and if the pulse oximeter reading and/or Doppler ultrasound wave form is abnormal, the patient needs brachial artery exploration.

Loss of radial pulse after reduction of the fracture or in the setting of an open penetrating injury should also be treated by exploring the brachial artery.

Whether or not one should obtain an arteriogram prior to surgical exploration of the brachial artery remains controversial. Advocates claim that arteriography confirms the arterial injury, prevents unnecessary surgery, and allows planning of the reconstruction. Others worry that it needlessly prolongs ischemia time, overasts cases where bone fragments impinge the artery, and runs the risk of allergic reaction and further damage to the artery at the catheter insertion site.

If ischemia has been present for a while with swelling, limited movement, and positive passive stretch, compartment pressures should be measured and appropriate fasciotomies performed.

Remember that the pain and signs of compartment syndrome may be absent if the median nerve has been injured and the hand is anesthetic.

ASSESSMENT OF REDUCTION

AP radiographs are used to assess the presence of a varus or valgus and medial or lateral displacement. Lateral radiographs assess posterior displacement, posterior tilt, and malrotation.

Varus is difficult to assess clinically in any position other than full extension. Radiographically, one can measure the angle between the longitudinal axis of the humerus and the physis of the capitellum, Bauman's angle, or a line connecting the distal medial epicondyle with the distal capitellum, the distal ossification margin line, or a line connecting the widest diameter of the metaphysis on the frontal view, the metaphyseal-diaphyseal angle. The measured angle is compared with that of the normal side. These measurements are subject to observer error and the position of the arm; cephalocaudal or caudalcephalad angulation of the x-ray beam more than 20° from the perpendicular distorts Bauman's angle and makes it unreliable. Forearm bones are often superimposed over the distal humerus, making interpretation all the more difficult. An angle between the midhumeral line and a line drawn down the ulna, the humeral-ulna angle, is most accurate. However, the elbow rarely can be fully extended to obtain this view in the treatment of the acute fracture.

Malrotation up to 50° is difficult to appreciate
on AP radiographs. Malrotation is readily observed on lateral radiographs by the discrepancy between the AP dimension of the proximal and distal fragments. Small degrees of malrotation are recognized by a double cortex seen posteriorly in the proximal fragment and seen as an inverted V in the metaphysis. In greater degrees of malrotation the two limbs of the V split into two columns joined by a sharp apex at the proximal end of the olecranon fossa. Such transcondylar lateral views of the distal fragment, however, do not demonstrate the direction of rotation of a transverse fracture; an external rotation deformity of any degree will look identical to an internal rotation deformity of the same degree.

The direction of rotation may be deduced from a true lateral of the proximal fragment, obtained by rotating the proximal fragment until the narrowest AP diameter is visualized. If, on such views, the capitellum lies anterior to the trochlea, then the distal fragment is internally rotated. If the capitellum is level with or posterior to the trochlea, then the distal fragment is externally rotated. If the trochlea is not ossified, the medial epicondyle, though more posteriorly placed, may be substituted as a landmark.

If the fracture is oblique in the coronal plane, the direction of rotation may be deduced by noting whether the medial or lateral spike lies anterior or posterior to the remaining proximal diaphysis.

Another technique can be used with the image intensifier to determine the direction of rotation by rotating the humerus from a true lateral of the distal fragment to a true lateral of the proximal fragment while noting the direction the forearm is being rotated. If the forearm is further rotated medially to obtain a true lateral of the proximal humerus, then the distal fragment is in a position of internal rotation and vice versa.

**Acceptability of Reduction**

Medial and lateral displacement and posterior tilt into extension have all been shown to be acceptable and to remodel with time.46-50

Varus malunion results in an unacceptable gunstock deformity, although the elbow functions normally with full flexion, extension, pronation, and supination. Ulnar nerve palsy has been described in cubitus varus related to anterior dislocation by a medial shift of the triceps.51 Valgus leaves an acceptable increased carrying angle, but may result in delayed ulnar nerve palsy52,53 or persistent lack of full elbow extension.54

Malrotation may contribute to the loss of initial fracture stability,55 but after healing does not affect function in the presence of normal shoulder motion.56 Most believe that spontaneous correction of rotational deformity does not occur,19,46,53,57,61 but others have suggested that some rotational deformity may remodel.10,25,50,58

**MALROTATION**

Each 10° of malrotation displaces the hand 2 cm to 3 cm when the elbow is flexed 150° at a normal carrying angle. Adding external rotation to varus or internal rotation to valgus will not move the hand much further than the position resulting from the angular deformity alone. Adding internal rotation to the varus or external rotation to valgus will displace the hand considerably, but all within the 23 cm total range of excursion from malrotation alone (Fig 4).

**LOSS OF MOTION**

All patients with displaced supracondylar fractures lack full extension of the elbow after initial healing, and extension improves gradually over 6 months. Flexion, especially in those with posterior tilt, improves with further growth. Pronation and supination are usually normal.

**VARUS MALUNION**

Varus malunion is unacceptable cosmetically. Its presence can only be appreciated clinically with the elbow in full extension. Varus is due to incomplete reduction unrecognized radiologically in the elbow treated in flexion.59 Traditionally, many believed that rotational deformity resulted in poor bone contact medially that allowed the fracture to rotate into varus.13,39,57,60-63 But Thomas and Alpar58 showed that patients with internal rotation deformities had no increased incidence
of varus, and Mann showed that patients with varus had no increased incidence of internal rotation. Of 12 cases of malrotation in the Ippolito et al study, 8 were seen with a normal carrying angle and three with valgus. Smith proposed that varus must occur if any rotation occurs in a fracture that runs obliquely from posterior proximal to anterior distal. Thomas and Alpar, however, have shown that varus occurs just as frequently following transverse as oblique fractures. Medial displacement and comminution have been implicated in its development. The rule of unequal growth in varus is uncertain and has only strong support in cases where the epiphysis itself has been affected.

Osteotomy for Varus Malunion

A lateral closing wedge, medial opening wedge, or dome osteotomy can be used to correct a varus deformity made through a medial, lateral, or posterior approach. Osteotomized fragments should be held by pins or external fixator. Slight medial displacement of the distal fragment is recommended. Because external rotation makes varus less apparent, some advocate externally rotating the forearm during correction; others feel it may contribute to instability. One or more complications including loss of correction, pin problems, stiffness, neuropaxia, or unsightly scar have been reported in one quarter to one half of the cases.

REFERENCES