THE 'FLOATING ELBOW' IN CHILDREN

SIMULTANEOUS SUPRACONDYLAR FRACTURES OF THE HUMERUS AND OF THE FOREARM IN THE SAME UPPER LIMB

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During a six-year period we prospectively studied eight children who presented with supracondylar fractures of the humerus and of the forearm on the same side. They were treated by prompt closed reduction, percutaneous fixation with Kirschner wires, and appropriate management of neurovascular and soft-tissue injuries. The results were assessed clinically and radiographically at a minimum of 12 months after injury. According to a clinical scoring system they were acceptable in seven children and poor in one.

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The common extension type of supracondylar fracture of the distal humerus in childhood is a serious injury. The incidence of fractures of the forearm in association with supracondylar fractures varies from 2% to 13% (Stanitski and Micheli 1980; Piggot, Graham and McCoy 1986) but there are few reports dealing specifically with the combined injury (Reed and Apple 1976; Stanitski and Micheli 1980; Papavasiliou and Nenopoulos 1986; Williamson and Cole 1992). When fractures of the upper arm and the forearm are present in the same limb, the elbow is effectively dissociated from the rest of the limb. Hence this injury has been named 'the floating elbow' (Stanitski and Micheli 1980).

On average, two children with a floating elbow are admitted to the Royal Belfast Hospital for Sick Children each year. Since 1987, we have studied these children prospectively to assess the outcome of management by prompt reduction and stabilisation of the fractures.

PATIENTS AND METHODS

Between 1987 and 1993, eight children were admitted to the Royal Belfast Hospital for Sick Children with com-

pletely displaced ipsilateral extension supracondylar fractures of the humerus and a range of forearm fractures (Table I). They were the result of indirect violence, usually a fall from a height on to the outstretched hand. Two of the supracondylar fractures of the humerus were open; one was Gustilo type I and one Gustilo type IIIa in a child who fell from a height of ten metres (Fig. 1).

The supracondylar fractures were completely displaced Gartland/Wilkins grade-3 extension injuries and were trea-

Fig. 1

Radiograph of a floating elbow in a nine-year-old boy who fell from a height of ten metres showing a Gustilo type-IIIa open extension supracondylar fracture of the humerus and comminuted displaced fractures of the distal diaphyses of the radius and ulna.

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Fig. 2a

Fig. 2b

Radiographs showing a grade-3 comminuted extension supracondylar fracture and a completely displaced fracture of the distal radial metaphysis (a). There is good position after closed reduction and percutaneous Kirschner-wire fixation (b).

ted by immediate closed reduction and percutaneous Kirschner-wire fixation, using a variety of fixation techniques (Fig. 2) (Gartland 1959; Wilkins 1991). The distal forearm fractures were treated by closed reduction and percutaneous Kirschner-wire fixation, similar to that described by Kapandji (1987) and Wilkins (1991). Only the radial fracture was stabilised, either by insertion of a single oblique Kirschner wire from the dorsal aspect of the wrist or by insertion of dorsal and radial Kirschner wires (Fig. 3). The distal fractures were treated by insertion of the Kirschner wires obliquely through the fracture line into the proximal fragment, producing a buttressing effect against redisplacement and avoiding transfixion of the growth plate with wires (Kapandji intrafocal technique). In the more proximal forearm fractures both fragments were transfixed by wires crossing the distal radial growth plate when necessary. All Kirschner wires were covered with a sterile dressing, left protruding through the skin and secured externally with Jurgens pin balls (Fig. 4).

The upper limb was splinted in a well-padded above-elbow backslab in a position of flexion which did not compromise the circulation. The forearm was placed in neutral rotation and the wrist was also in a neutral position with respect to flexion and extension. The open fractures were debrided and closed by delayed primary suture or skin grafting.

In one patient the injured arm was ischaemic on admission, with absent pulses and a white hand. The circulation returned to normal after immediate reduction and fracture stabilisation. Another patient (case 2, Table II) developed a compartment syndrome and required exploration of the

Fig. 3a

Fig. 3b

Radiographs showing the Kapandji intrafocal technique for stabilising the distal radial fracture. Each wire is inserted through the fracture and engages but does not penetrate the far cortex. This buttresses the fracture against redisplacement.

Fig. 4

AP radiograph of the same supracondylar fracture as in Figure 2 just before removal of the wires. Note the use of three Kirschner wires and Jurgens pin balls.

brachial artery 24 hours after injury. An intimal tear and a thrombosed segment of artery were resected and replaced by a vein graft, in conjunction with extensive fasciotomies

of the volar compartment of the forearm.

On initial assessment there were two median, one anterior interosseous and two ulnar nerve palsies. Another ulnar nerve palsy was found after fixation of the fracture by a Kirschner wire inserted via the medial epicondyle, and was considered to be iatrogenic.

All percutaneous wires were removed after three to four weeks to allow early mobilisation of the elbow. Forearm fractures required immobilisation for four to eight weeks in below-elbow casts.

Patients were recalled for a detailed clinical and radiographic evaluation at between 12 and 45 months from injury and they and their parents were questioned about pain, stiffness and cosmesis. The range of elbow flexion-extension, forearm rotation, wrist movements and the carrying angles were measured by goniometers in both the injured and non-injured limbs (Table II). Radiographs were obtained of both elbows, forearms and wrists. Long films of both elbows were obtained in extension and supination on a single film in order to measure Baumann's angle in both upper limbs. We performed a detailed neurovascular examination and compared the findings with those recorded on admission and after operation. The final outcome was graded by the first author, who had not been involved in the management of the children, according to a combination of Flynn's criteria for isolated supracondylar fractures and a grading of forearm rotation and wrist movement (Flynn, Matthews and Benoit 1974; Steele and Graham 1992). Many children had movement in excess of the normal range for adults but this was not considered to be functional and did not affect grading (Table III).

RESULTS

According to our modified criteria there were seven acceptable (four excellent, two good and one fair) and one poor result. The patient with the poor result had a cubitus varus deformity with a carrying angle of 6° of varus compared

Table I. Details of eight patients with supracondylar fractures of the humerus and forearm fractures

Case	Age (yr)	Sex	Side	Mechanism of injury	Supracondylar fracture classifications Gartland/Gustilo	Forearm fracture site	Treatment of the supracondylar fracture*	Treatment of the forearm fracture*
1	4	M	R	Fall 1 m	3	Metaphysis	CR/LMK	CR/DK
2	16	M	L	Fall 6 m	3	Epiphysis-Salter-Harris 2	CR/LMK	CR/DRK
3	7	M	R	Fall 3 m	3	Metaphysis	CR/LMK	CR/DK
4	9	M	L	Fall 10	3/IIIa	Diaphysis distal third	CR/LMK	CR/DRK
5	8	F	L	Fall from skateboard	3	Metaphysis	CR/LLP	CR/DRK
6	5	M	L	Fall 1 m	3/I	Metaphysis	CR/LLMK	CR/DRK
7	11	M	L	Fall 1.5 m	3	Epiphysis-Salter-Harris 2	CR/LMK	CR/DRK
8	7	M	R	Fall from bicycle	3	Diaphysis distal third	CR/LMK	CR/DRK

* CR, closed reduction; K, percutaneous K-wire fixation (L-lateral, LL-double lateral, M-medial, D-dorsal, R-radial)

Table II. Results in eight patients

Case	Side	Review period (mth)	Arc of elbow flexion (degrees)	Carrying angle (degrees)	Arc of forearm (degrees; sup/pron)	Arc of wrist (degrees; flex/ext)	Complications	Comment	Modified Flynn classification
1	R	45	R 148 (-10 to 138) L 140 (-4 to 136)	0 0	170 (90/80) 160 (90/70)	162 (80/82) 170 (84/86)	Temporary ulnar nerve palsy		Excellent
2	L	42	R 150 (-10 to 140) L 124 (3 to 127)	5 10	229 (135/94) 205 (112/93)	120 (50/70) 119 (53/66)	Temporary ulnar nerve palsy Temporary median nerve palsy Brachial artery intimal tear	Elbow function reduced by 26° Carrying angle increased by 5° Split-skin graft scar	Fair
3	R	39	R 140 (2 to 142) L 140 (2 to 142)	-6 10	135 (80/50) 170 (90/90)	106 (46/60) 108 (46/62)	Cubitus varus 6°	Cubitus varus 6°	Poor
4	L	32	R 158 (-12 to 146) L 154 (-10 to 144)	12 10	175 (100/75) 175 (95/80)	131 (59/72) 138 (60/78)		Delayed primary suture scar	Excellent
5	L	14	R 150 (-10 to 140) L 138 (-7 to 131)	8 6	160 (80/80) 160 (85/75)	162 (80/82) 158 (80/78)		Elbow flexion reduced by 9°	Good
6	L	23	R 150 (-5 to 145) L 149 (-5 to 144)	8 10	175 (100/75) 170 (100/70)	128 (64/64) 128 (64/64)			Excellent
7	L	20	R 148 (-5 to 143) L 145 (-5 to 140)	8 8	170 (90/80) 160 (90/70)	170 (89/90) 170 (80/90)	Temporary median nerve palsy	Forearm rotation reduced by 10°	Excellent
8	R	12	R 136 (0 to 138) L 146 (-5 to 141)	7 10	145 (75/70) 180 (90/90)	145 (65/80) 160 (80/80)	Anterior interosseous nerve palsy, temporary	Forearm rotation reduced by 35°	Good

Table III. Clinical scoring system based on Flynn's criteria for isolated supracondylar fractures. All measurements are in degrees. Many children had ranges of forearm rotation and wrist flexion/extension well in excess of the normal adult range. Elbow data are a comparison between the injured and non-injured sides

Overall grade	Wrist		Forearm rotation		Elbow function	Elbow cosmesis
	Flexion	Extension	Supination	Pronation	Loss of flexion/extension	Carrying angle change
Excellent	70 to > 80	70 to > 80	75 to > 90	70 to > 85	0 to 5	0 to 5
Good	60 to 69	60 to 69	60 to 74	55 to 69	6 to 10	6 to 10
Fair	50 to 59	50 to 59	45 to 59	40 to 54	11 to 15	11 to 15
Poor	< 50	< 50	< 45	< 40	> 15	> 15

with 10° valgus on the opposite site on both clinical measurement and by the Baumann angle. Osteotomy was not offered and the functional result was excellent.

Considerable scarring was noted in the patient with a Gustilo type-IIIa open fracture and in the child who had a repair of the brachial artery and a fasciotomy. There was no evidence of vascular impairment or ischaemic contracture in any patient. All nerve injuries had recovered fully at the time of final evaluation, including the iatrogenic ulnar palsy. At follow-up, radiographs were taken of all epiphyses which had been transfixed by wires. There was no evidence of growth disturbance.

DISCUSSION

Most of these injuries are caused by a fall on the outstretched hand and in these children the humeral fracture is a typical extension type of supracondylar fracture. The forearm fracture is usually in the distal third of the forearm, either a Salter-Harris type-2 epiphyseal separation or in the metaphysis or the distal third of the diaphysis. The mechanism of injury appears to be a fall on the outstretched hand

with the wrist dorsiflexed, the forearm pronated and the elbow extended. The forearm fails in the distal third and the resultant moment of force is sufficient to cause an extension-type supracondylar fracture of the distal humerus.

If the fracture of the forearm is more proximal than the junction of the middle and distal thirds, the lever arm of the proximal forearm segment is too short to generate the moment of force required to produce the ipsilateral humeral fracture. Most of our children fell from a height and the incidence of neurovascular and soft-tissue injury was correspondingly higher than that reported by previous authors (Reed and Apple 1976; Stanitski and Micheli 1980; Papavasiliou and Nenopoulos 1986; Williamson and Cole 1992).

In most cases the supracondylar fracture can be managed by closed reduction and percutaneous Kirschner-wire fixation. These supracondylar fractures are usually completely displaced, sometimes comminuted and very unstable. Crossed medial and lateral wires are required for stability and it is sometimes necessary to add a third wire (Fig. 4) (Zionts, McKellop and Hathaway 1994). We do not believe that there is a place for conservative management of the

Fig. 5a

Fig. 5b

Fig. 5c

Radiographs showing a floating elbow with diaphyseal fractures of the distal third of the radius and ulna, before (a) and four weeks after fixation by a longitudinally-orientated Kirschner-wire (b), just before removal of the wire. There is good remodelling at three months after injury (c).

elbow fracture as has been suggested (Smyth 1956; Reed and Apple 1976; Papavasiliou and Nenopoulos 1986). Traction does not offer anatomical reduction or access to the limb in these serious injuries. Cast treatment in flexion was contraindicated in all of our patients because of swelling, neurovascular injury or open fractures, and it is associated with a higher incidence of cubitus varus deformity (Reed and Apple 1976). We feel that the supracondylar fracture deserves priority because of the much greater incidence of associated complications. Once it is stabilised the management of the forearm fracture, open injuries, vascular impairment and nerve palsies is made easier.

Most previous authors have advised closed reduction of forearm fractures (Reed and Apple 1976; Stanitski and Micheli 1980; Papavasiliou and Nenopoulos 1986) but maintenance of reduction and access to the limb for neurovascular monitoring, dressings and the closure of open fractures may then be difficult. The fractures are invariably displaced dorsally and sometimes radially, and the optimum position for cast immobilisation in pronation and palmar flexion may make it difficult to feel the radial pulse and

impossible to test combined wrist and finger extension.

Stabilisation of both fractures gave prompt relief of pain and rapid resolution of swelling, and apart from one temporary palsy of the ulnar nerve, fixation was free from complications. No child had a pin-track infection or loss of fixation. The use of Jurgen pin balls stabilises the pin-skin interface, reduces the risk of infection and abolishes the risk of migration of the Kirschner wire. These are important considerations when three to five percutaneous Kirschner wires are used. The epiphyseal and metaphyseal fractures are much easier to reduce and hold by the Kapandji intrafocal technique than distal-third diaphyseal fractures. These require an intramedullary, longitudinally-orientated, Kirschner wire (Fig. 5), as described by Wilkins (1991).

The floating elbow in children is a serious injury. Reduction and stabilisation of the displaced fractures, careful neurovascular monitoring and good soft-tissue care will produce an acceptable result in most cases.

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