We performed an audit of 71 children with consecutive displaced, extension-type supracondylar fractures of the humerus over a period of 30 months. The fractures were classified according to the Wilkins modification of the Gartland system. There were 29 type IIA, 22 type IIB and 20 type III. We assessed the effectiveness of guidelines proposed after a previous four-year review of 83 supracondylar fractures. These recommended that: 1) an experienced surgeon should be responsible for the initial management; 2) closed or open reduction of type-IIB and type-III fractures must be supplemented by stabilisation with Kirschner (K-) wires; and 3) K-wires of adequate thickness (1.6 mm) must be used in a crossed configuration.

The guidelines were followed in 52 of the 71 cases. When they were observed there were no reoperations and no malunion. In 19 children in whom they had not been observed more than one-third required further operation and six had a varus deformity. Failure to institute treatment according to the guidelines led to an unsatisfactory result in 11 patients. When they were followed the result of treatment was much better. We have devised a protocol for the management of these difficult injuries.

Received 19 October 1998; Accepted after revision 30 April 1999.

Supracondylar fracture of the humerus is the second most common fracture in children (16.6%) and the most frequent before the age of seven years.1 In 1959 Gartland2 commented that "it is interesting to observe the trepidation with which men, otherwise versed in trauma, approach a fresh supracondylar fracture". The dread of this injury still remains. Treatment is controversial and often technically difficult; complications are common. Cubitus varus is the most frequent problem with a mean incidence of 30% in the series reviewed by Smith.3 This deformity is due to medial tilting of the distal fragment, associated with rotation.3 It does not remodel with growth,4-6 is not progressive and is not due to physeal injury.7 Injury to any of the three major nerves around the elbow occurs in 6% to 16% of cases.7 The radial pulse is absent in about 3% after reduction of the fracture.8 Volkman"s ischaemic contracture is rare, with an incidence of 1.1 in 1000,9 but is still seen.10-12 Stiffness of the elbow may occur, particularly after repeated manipulation and the use of the posterior approach for open reduction. In most cases, however, there is improvement with time and the functional result is not greatly impaired.5,6 A variety of methods of treatment for displaced fractures has been recommended including closed reduction and immobilisation,2,4,13-18 traction by various methods19-22 and closed23-32 or open reduction33-36 stabilised by Kirschner (K-) wires. Although some authors are not in favour of closed reduction and immobilisation,11 particularly for severe injuries, this treatment remains popular.31 Others recommend stabilisation by K-wires for all displaced fractures.31

The aim of treatment is to gain a functional and cosmetically acceptable upper limb with a normal range of movement.37 Ideally, this should be achieved by one definitive procedure. A change in treatment because of loss of reduction may be psychologically traumatic to the child, may give rise to parental anxiety38 and is associated with an increased risk of a poor outcome.11

Before October 1994 there were no specific guidelines for the treatment of these fractures at our institution. They were managed by a number of different regimes which were supervised by several orthopaedic/trauma consultant surgeons. Between January 1990 and July 1994 a retrospective review of 93 displaced fractures was performed with adequate follow-up in 83.39 All the injuries were
classified using the modification of the Gartland system\textsuperscript{2} by Wilkins\textsuperscript{40} (Table I; Fig. 1). The results were excellent in all type-IIA injuries. In type-IIB and type-III fractures there was an unacceptable rate of reoperation of 29\% (19 of 65 cases) for redisplacement. In total, these 19 patients had 42 operations. The indications for reoperation in this retrospective study were reangulation or redisplacement of the fracture or rotation of the fragments predisposing to medial tilting and subsequent varus deformity. In eight of the 65 patients there was an unsatisfactory outcome because of cubitus varus ranging from 5\° to 10\°. So far two of these children have required corrective surgery. Analysis of the

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>I</td>
<td>Undisplaced fracture</td>
</tr>
<tr>
<td>IIA</td>
<td>Greenstick fracture with posterior angulation</td>
</tr>
<tr>
<td>IIB</td>
<td>Greenstick fracture with malrotation + posterior angulation</td>
</tr>
<tr>
<td>III</td>
<td>Completely displaced fracture</td>
</tr>
</tbody>
</table>
patients who required reoperation suggested that the following factors led to a suboptimal result.

1) Inexperience of the surgeon responsible for the initial management of the fractures.
2) Failure to supplement closed reduction of type-IIIB and type-III fractures with K-wires.
3) The use of K-wires of less than 1.6 mm in diameter.
4) The use of a lateral K-wire configuration.

As a result the following guidelines for treatment were proposed.

1) An experienced surgeon should be responsible for the initial management. Such a surgeon was defined as one who could competently perform initial closed reduction and fixation by crossed K-wires and if necessary open reduction. Traction and conservative methods of treatment were not considered therapeutic options for type-IIIB and type-III fractures within these guidelines.
2) Closed or open reduction of type-IIIB and type-III fractures must be supplemented with stabilisation by K-wires. The indication for open reduction was failure of closed manipulation.
3) K-wires of adequate thickness (1.6 mm) must be used in a crossed configuration.

After the introduction of these guidelines a further audit of 71 consecutive cases of displaced supracondylar fracture of the humerus was carried out over a 30-month period. We now report the results in regard to the protocol of treatment and the provision of resources.

Patients and Methods

Between October 1994 and March 1997, 71 consecutive children with displaced, extension-type supracondylar fractures of the humerus were entered into the study. Inpatient care and outpatient follow-up were analysed using hospital notes, details of the operation, and plain radiographs.

There were 41 boys and 30 girls with a mean age of six years (1 to 11). The fractures were classified according to the Wilkins\(^2\) modification of the Gartland\(^2\) system. There were 29 type-IIA, 22 type-IIIB and 20 type-III fractures. There was one grade-I open injury occurring in a type-III fracture and one case of an associated ipsilateral fracture of the distal radius.

In six children the radial pulse was absent on presentation, but distal pulses returned after reduction of the fracture in five. The sixth child required further intervention. There were neurological complications in five children, in three palsy of the median nerve and in two injury to the radial nerve. All of which resolved within eight weeks.

The patients were allocated retrospectively into two groups based on the guidelines for treatment suggested by the previous four-year audit. In group 1 (52 patients) the guidelines were followed but in group 2 (19) they were not observed. This allocation was made in a blinded fashion after assessing the management of a patient but without knowledge of the outcome. The two groups were then compared with regard to the rate of reoperation, the range of elbow movement and cosmetic deformity.

Patients were followed up until there was full recovery or the clinical situation was stable. This ranged from three months to one year on the basis that varus angulation occurs as a result of malreduction and not abnormal growth.

Results

Of the 29 type-IIA fractures, 22 were managed non-operatively by a collar and cuff or immobilisation in plaster. In seven, posterior angulation of the fracture led to a humero-capitellar angle of less than 0° and it was decided to perform a closed reduction. All 29 children in this group had an excellent outcome with a full range of movement and a normal carrying angle. No further operation was required after the primary procedure.

Table II gives the methods of treatment used for the 22 type-IIIB and 20 type-III fractures.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Type of fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaster immobilisation</td>
<td>IIB  3 IIB  0</td>
</tr>
<tr>
<td>Closed reduction and immobilisation</td>
<td>7 1</td>
</tr>
<tr>
<td>Closed reduction and K-wire fixation</td>
<td>7 10</td>
</tr>
<tr>
<td>Open reduction and K-wire fixation</td>
<td>5 9</td>
</tr>
</tbody>
</table>

Table III. The results of treatment in the 22 type-IIIB and 20 type-III fractures

<table>
<thead>
<tr>
<th>Outcome*</th>
<th>Type of fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single operation</td>
<td>IIB  14 IIIB  18</td>
</tr>
<tr>
<td>Reoperation</td>
<td>5 2</td>
</tr>
<tr>
<td>Normal carrying angle (degrees)</td>
<td>20 16</td>
</tr>
</tbody>
</table>

*three type-II fractures were treated non-operatively
Analysis of the 11 unsatisfactory results showed that closed reduction of type-IIB and type-III fractures without stabilisation by K-wires led to an unsatisfactory result in five out of eight patients. They required four further operations for loss of reduction and one for varus deformity. This occurred in a type-IIB fracture which redisplaced and had no operative treatment.

Use of lateral K-wires alone led to an unsatisfactory result in four out of seven patients because of redisplacement of the fracture despite an initial anatomical reduction. One of these had no further surgical treatment and developed cubitus varus (Fig. 2). In the other three children who had a second operation two developed varus malunion. In one, lateral K-wires were used again and in the other crossed K-wires failed to engage the proximal cortex.

Non-operative treatment of type-IIB fractures led to cubitus varus in one out of three children treated by this method.

Four operations were performed by inexperienced surgeons. Three of these had further surgery. In one patient poor reduction of a type-III fracture, stabilised by fixation with cross wires led to cubitus varus.

There were three complications related to operative treatment. Two patients developed pin-site infection which responded to antibiotics and one had a postoperative neurapraxia of the radial nerve which resolved spontaneously. There were no cases of infection in those fractures requiring open reduction and none of Volkmann’s ischaemic contracture.

Discussion

The many different methods advocated for supracondylar fractures of the humerus in children suggest that no single technique is suitable for all types of fracture. The displaced supracondylar fracture represents a spectrum of injury from type IIA with minor swelling of soft tissues to type III with considerable swelling and potential neurovascular complications. A selective approach to treatment is required based on the classification of the fracture and the soft-tissue complications present.

Closed reduction and immobilisation require 120° of elbow flexion to maintain stable reduction. There are two disadvantages to this method, described by McLaughlin as the “supracondylar dilemma”. Flexion to 120° in a swollen elbow may compromise the circulation but less flexion predisposes to loss of reduction. This method has a high incidence of poor results when used for all types of fracture. Some authors have used manipulation and immobilisation in plaster as their first line of treatment and then remanipulate or change their treatment if there is loss of reduction. Further manipulation, however, predisposes to stiffness and myositis ossificans. Mitchell and Adams reported an incidence of 60% of cubitus varus deformity using this method; 19% of their patients had three manipulations. Eleven of their patients had less severe injuries, however, equivalent to Gartland-Wilkins type IIA of whom nine had satisfactory results. Pirone et al found that only 51% of patients had excellent results using manipulation.
and plaster and concluded that its use was inappropriate for the displaced supracondylar fracture. Their series, however, did not provide individual results for type-IIA and type-IIB fractures. Recently, Hadlow et al. have recommended manipulation and immobilisation in plaster for all types of fracture, despite 31% of children requiring further operative treatment and the development of a number of varus deformities when loss of position was unrecognised with type-III fractures treated in plaster.

We believe that closed reduction and immobilisation are satisfactory for type-IIA fractures only. This fracture usually presents with mild swelling and vascular complications are infrequent. Eight patients in our series with type-IIB and type-III fractures had non-guideline treatment by closed reduction without fixation and in six of these the fracture redisplaced. Type-IIA fractures usually do not have neurovascular complications or major swelling and can be managed in flexion in a collar and cuff or plaster. They may not even require reduction provided that the angle of the distal humeral articular surface measures at least 0° with the shaft. We treated 22 type-IIA fractures with immobilisation alone and all had satisfactory results. We did not encounter a situation where there was sufficient elbow swelling to compromise the circulation. If this had occurred we would consider this to be an indication for K-wire stabilisation of a type-IIA fracture.

Skin traction and skeletal traction have been recommended particularly when there is concern regarding swelling of soft tissues. The incidence of cubitus varus, however, may be high when compared with percutaneous pinning. Hospital stay is likely to be longer with increased costs. Volkmann’s contracture has been reported. We have not found marked swelling to be an obstacle to closed pinning or open reduction and discontinued using traction after our initial audit because of poor results in over half of our cases.

Closed reduction and percutaneous pinning are now widely recommended. Wilkins has advocated stabilisation by K-wires for all displaced fractures. The inpatient stay is reduced and the elbow can be immobilised in a more extended position reducing concern about limb perfusion in injuries with major swelling of soft tissues. Flynn et al. found no evidence of physeal injury secondary to insertion of K-wires when smooth wires were used. Pin-track infection occurred in only two pins in our series without sequeleae. Iatrogenic injury to the ulnar nerve may occur even when the medial epicondyle is palpable. Lateral K-wires have been recommended to avoid this complication. Biomechanical studies have shown, however, that a crossed medial and lateral K-wire configuration is more stable than lateral pins alone. Redisplacement of the fracture has been reported to be significant after the use of lateral K-wires. A lateral K-wire configuration may not allow full extension of the elbow thus preventing examination of the carrying angle at operation. In our study redisplacement occurred in four out of seven patients when a lateral pin configuration was used. We would therefore recommend identification of the ulnar nerve with a medial incision and crossed K-wire stabilisation. We had no iatrogenic injuries to the ulnar nerve.

The indications for open reduction and pin fixation include a fracture which is irreducible by closed methods; an open fracture and vascular injury. Open reduction has been advocated as the primary procedure in all cases. Others have condemned this approach because of concerns about infection and loss of movement. Those series which demonstrated significant loss of movement, however, were reported by surgeons who used a posterior approach.
approach or resorted to surgery only after repeated closed manipulations.\textsuperscript{33,35} Open reduction was required in 14 out of 31 patients stabilised by K-wires. There were no episodes of superficial or deep infection and no functional loss of movement.

Four patients in our series were treated initially by inexperienced surgeons and all had a poor result with either reoperation or development of a cubitus varus. Surgeons of adequate experience were available on these particular occasions but there was a failure to request advice or assistance. The other patients were treated by experienced surgeons, but the results were poor when the guidelines were not followed. These problems have since been addressed. These fractures are now managed by two consultant paediatric orthopaedic surgeons who should be informed of all patients undergoing operative treatment.

There was a clear difference in results when the guidelines were not followed. Although a satisfactory outcome may be obtained in terms of limb function with further surgery after the primary operation, we believe that initial treatment should be definitive. A second surgical procedure is more difficult to perform and can be associated with an adverse outcome.\textsuperscript{11} Is it acceptable for a child to be subjected to the psychological trauma of a second operation because of inappropriate initial treatment? Based on our guidelines we have now introduced a treatment protocol (Figs 3 and 4) for use at this hospital.

Although the audit loop may not have been technically closed we feel that the difference in outcome between the guideline and non-guideline groups is so clear that a further audit to define the best clinical management would be inappropriate. In effect this would be an audit of whether surgeons are capable of following guidelines. Our study has pinpointed the deficiencies in both the operative management of the supracondylar fracture of the humerus in children as well as flaws in the appropriate use of available resources. These deficiencies have both now been addressed with the introduction of a formal treatment protocol as well as an alteration in the emergency senior cover of injuries in children as discussed above.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


