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Comparison of two methods of percutaneous pin fixation in displaced supracondylar fractures of the humerus in children

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ABSTRACT

Purpose. To conduct a prospective randomised controlled study to compare the stability and risk of nerve injury between fractures treated by medial-lateral pin fixation and those treated by 2-lateral pin fixation.
Methods. Patients with displaced supracondylar fractures admitted between May 2000 and December 2001 were recruited into the study. They were randomised to treatment either with medial-lateral pin fixation (n=34) or with 2-lateral pin fixation (n=32).
Results. 66 children with the mean age of 5.78 years were admitted during the study period. 11 of them were lost to follow-up. The mean follow-up period of the remaining 55 patients was 8.93 months. The difference in the carrying angle between injured and normal elbows was 3.57° and 3.70° in medial-lateral pin fixation and 2-lateral pin fixation, respectively. The extension and flexion loss was 7.14° and 8.68° respectively in medial-lateral pin fixation, and 7.11° and 11.26° respectively in 2-lateral pin fixation. The Baumann angle difference was 5.96° in medial-lateral pin fixation, and 5.30° in 2-lateral pin fixation. The difference in the medial epicondylar epiphyseal angle was 6.07° in medial-lateral pin fixation and 6.92° in 2-lateral pin fixation. Statistical analyses show that these differences are not significant. Five iatrogenic ulnar nerve injuries developed in the group treated by medial-lateral pin fixation, while 2 ulnar nerve and one radial nerve injuries were seen after 2-lateral pin fixation. Again the differences were not statistically significant.
Conclusion. Both methods of fixation were comparable in terms of stability, duration of bone healing, and risks of injury to the nerve.

Key words: *child; elbow joint; fracture fixation; humeral fractures*

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INTRODUCTION

Supracondylar fracture of the humerus in children is one of the most common fractures seen in the paediatric orthopaedic clinic setting worldwide. It is a fracture that occurs at the supracondylar area or the metaphysis of the distal humerus and accounts for 65.4% of upper extremity fractures in children according to Boyd and Altenberg.[1] Traditionally this type of fracture is associated with a high rate of malunion, nerve injury, and vascular complication. The incidence of cubitus varus deformity after treatment was about 5% according to Flynn et al.,[2] while Arino et al.[3] reported that it was almost 21%. In a prospective study, Chai[4] reported that 8 (15%) of 54 patients developed iatrogenic ulnar nerve deficit after treatment with medial-lateral pin fixation.

Closed method of treatment is generally preferred to the open method, unless the fracture is complicated by vascular or nerve injury that requires exploration. The recommended method of percutaneous pin placement varies among authors. Swenson[5] and Casiano[6] described the use of 2 crossed pins, one inserted medially and one laterally. This method of medial-lateral pin fixation provides good stability of fixation but carries the risk of ulnar nerve injury. Arino et al.[3] recommended 2-lateral pins that could be inserted either crossed or parallel to the lateral condyle. This 2-lateral pin fixation avoids pin penetration over the medial aspect of the elbow but the stability that this technique provides might not be adequate to maintain reduction. Current interest is mainly focused on the configuration of pin for fixation that provides adequate stability with the lowest risk of iatrogenic nerve injury. Therefore, we conducted this prospective study to compare the outcomes of treatment with medial-lateral pin fixation and 2 lateral-parallel pin fixation.

MATERIALS AND METHODS

A prospective randomised controlled study was conducted from 1 May 2000 to 31 December 2001. All children with displaced supracondylar fractures (Gartland[7] type II and III) who presented to the casualty unit (Accident and Emergency Department) or the paediatric orthopaedic out-patient clinic of this institution were recruited in this study. The inclusion criteria were as follows:

(1) age between 1 and 12 years;
(2) those presenting within 3 days of injury;
(3) no previous fracture in either elbow, and
(4) no concomitant fracture or other injury in the same limb that will alter the treatment protocol of the supracondylar fractures.

Figure 1 The straight lateral skin traction for displaced supracondylar fracture of humerus in children.

All procedures and protocols used in this study had been approved by the medical ethics committee of our institution.

Children with fractures are usually first seen in the casualty unit. The orthopaedic doctor on call will examine the child, assess the vascular and neurological status, and review the radiographs of the elbow. All cases of displaced supracondylar fractures of humerus were admitted. They were put on forearm skin traction with the elbow in full extension (Fig. 1). Evaluation of the neurology and vascular status was repeated in the ward. After obtaining the informed consent for the study and surgery, the patients would be kept fasted for surgery. Fluid balance was maintained with intravenous drip and blood haemoglobin level was monitored. Surgery would be arranged for either the same day or the following morning. The main investigator would perform the randomisation by drawing lots—odd numbers signify medial-lateral pin fixation, while even numbers would be treated by 2-lateral pin fixation.

Surgery was performed by senior orthopaedic trainees supervised by one of the authors. After general anaesthesia was administered, the patient would be placed supine with the injured upper arm at the side of the table. Image intensifier was placed along the table from caudal end of the patient. The injured elbow was placed on the plate of the image intensifier. Since the paediatric elbow was relatively small, the plate of image intensifier usually sufficed to function as an arm support. Closed manipulative reduction was performed and the reduction was confirmed with the image intensifier. If the reduction was acceptable, the surgeon would scrub up, clean, and drape the injured

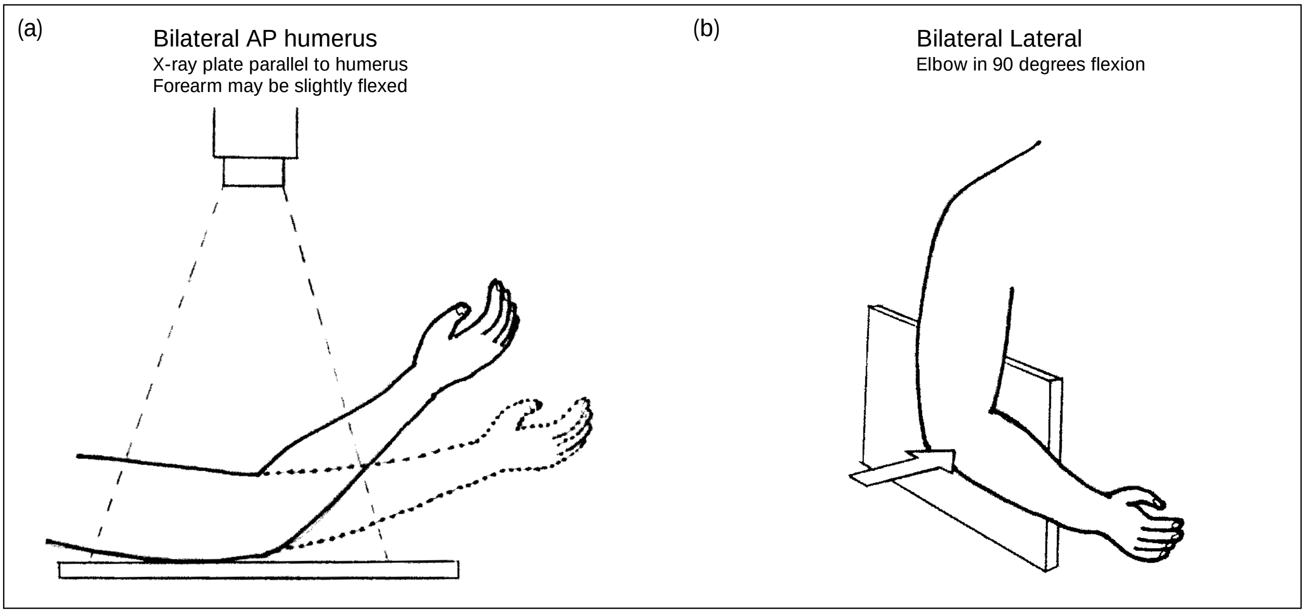

Figure 2 Instruction note attaching onto the standard radiograph request form: **(a)** position for anteroposterior (AP) view, and **(b)** position for lateral view.

Table 1
Modified Flynn's criteria to evaluate outcome of treatment

Result	Rating	Carrying-angle loss (°)	Flexion loss (°)	Extension loss (°)
Satisfactory	Excellent	0–4.9	0–4.9	0–4.9
	Good	5–9.9	5–9.9	5–9.9
	Fair	10–14.9	10–14.9	10–14.9
Unsatisfactory	Poor	≥15	≥15	≥15

arm to the axilla. The image intensifier would also be draped. The fracture would again be reduced and subsequently fixed with pins according to the selected configuration.

After the procedure, neurovascular status would be reviewed again in the ward by one of the investigators. Reduction and fixation of fracture would be confirmed by radiography, and the child would usually be discharged on the first or second postoperative day. All the patients were followed up at the paediatric orthopaedic out-patient clinic and reviewed by one of the authors. Plaster cast was usually removed after 3 weeks when there was evidence of callus formation. The second visit would be 6 weeks later where radiological evaluation would be performed. We attached specific instructions with drawings to the standard radiograph request form to ensure correct positioning of the elbow (Fig. 2). To obtain an anteroposterior view, the posterior aspect of upper arm was placed flat on the cassette. The X-ray tube was centred at the distal humerus perpendicular to the cassette. We allowed slightly flexed elbow because at 6 weeks, after removal of the plaster cast, some children might not be able to fully extend the elbow. For the lateral view, the elbow was positioned in 90° flexion and the cassette placed on the medial side of elbow joint. The X-ray tube was positioned at the elbow perpendicular to the cassette.

Subsequent follow-up would be done 6-weekly. All the clinical parameters were based on the last evaluation when full range of elbow motion was achieved. We considered deviation in all these parameters at this stage due to loss of reduction. We had to assume that all fractures would be fixed in perfect reduction based on intra-operative imaging. Cases with complications would undergo a different follow-up protocol depending on the nature of the problem. They were seen more frequently and would not be discharged until the condition completely recovered.

Table 2
Duration for various stages of treatment

Duration	Minimum	Maximum	Mean
Injury to admission (hours)	0.33	72	7.23
Injury to surgery (hours)	7	74	27.98
Hospitalisation (days)	1	4	2.86

Table 3
Duration from injury to surgery for the 2 methods of pin fixation

Injury to surgery (hours)	No. of patients receiving the method of pin fixation		Total No. of patients
	Medial-lateral	2-lateral	
0–23.9	6	6	12
24–47.9	22	20	42
48–71.9	4	5	9
≥72	2	1	3

Flynn's criteria for grading[2] involved the evaluation of carrying angle loss and total range of motion loss. In order to compare the stability of both methods of fixation, we modified the second component of the grading system and looked separately into extension loss and flexion loss (Table 1).

All data were compiled and calculated with Statistical Package for the Social Sciences (Windows version 10.0; SPSS Inc., Chicago, US). For carrying angle, elbow flexion, elbow extension, Baumann angle,[8] and medial epicondylar epiphyseal (MEE) angle,[9] we looked into the value of differences comparing the treated side with the uninjured side. We then compared these values between the 2 groups treated with different method of fixation and analysed them statistically with Student *t* test. Since the incidence of nerve injuries was small in number, we used Fisher's exact test to compare the 2 methods of fixation.

RESULTS

66 children were treated for displaced supracondylar fracture of humerus during the study period. The mean age was 5.78 years (standard deviation, 0.08 years; range, 1.08–11.08 years). 34 patients were treated with medial-lateral pin fixation and 32 patients were treated with 2-lateral pin fixation.

The duration from injury to admission to the hospital ranged from 0.33 to 72 hours, with a mean of 7.23 hours (Table 2). 61 patients were brought to the hospital within 24 hours of suffering the injury, 2 patients between 24 and 48 hours after injury, and 3 patients between 48 and 72 hours after injury. The duration from injury to surgery ranged from 7 to 74 hours (mean, 27.98 hours). Both groups under study had a similar pattern of duration from injury to surgery (Table 3).

11 (16.7%) of the 66 patients defaulted follow-up after the plaster casts were removed. Attempts to contact the families by phone and mail failed and finally on home visit, we found that some families had relocated during the follow-up period. Eventually, only 55 (83.3%) of the 66 patients were available for outcome analysis. The mean follow-up duration for the remaining 55 patients was 8.93 months (range, 3.13–14.73 months).

Table 4
Comparison of carrying-angle loss between 2 methods of pin fixation

Carrying-angle loss (°)	No. of patients receiving the method of pin fixation		Total No. of patients
	Medial-lateral	2-lateral	
0–4.9	21	22	43
5–9.9	4	2	6
10–14.9	2	1	3
>15	1	2	3
Total	**28**	**27**	**55**

Table 5
Elbow extension loss according to method of pin fixation

Extension loss (°)	No. of patients receiving the method of pin fixation		Total No. of patients
	Medial-lateral	2-lateral	
0–4.9	14	16	30
5–9.9	7	6	13
10–14.9	3	1	4
>15	4	4	8
Total	**28**	**27**	**55**

Table 6
Elbow flexion loss according to method of pin fixation

Flexion loss (°)	No. of patients receiving the method of pin fixation		Total No. of patients
	Medial-lateral	2-lateral	
0–4.9	9	7	16
5–9.9	9	6	15
10–14.9	4	5	9
>15	6	9	15
Total	**28**	**27**	**55**

Table 7
Analysis of carrying-angle loss, elbow extension loss, and elbow flexion loss between the medial-lateral pin fixation and 2-lateral pin fixation by using Student *t* test

Parameter	Medial-lateral pin fixation (mean±SD)	2-lateral pin fixation (mean±SD)	p value (Student *t* test)
Carrying-angle loss (°)	3.57±4.67	3.70±4.24	0.913
Elbow extension loss (°)	7.14±9.25	7.11±10.8	0.991
Elbow flexion loss (°)	8.68±8.64	11.26±10.4	0.322

Table 8
Analysis of Baumann angle loss and MEE angle loss using Student *t* test

Parameter	Medial-lateral pin fixation (mean±SD)	2-lateral pin fixation (mean±SD)	p value (Student *t* test)
Baumann angle loss (°)	5.96±5.6	5.30±5.0	0.646
MEE angle loss (°)	6.07±5.1	6.93±6.6	0.597

43 out of 55 patients had a carrying-angle loss of 0° to 4.9°, which was considered to be an excellent result (Table 4). 21 of them had medial-lateral pin fixation, while 22 had 2-lateral pin fixation. Of the 6 patients rated as having achieved a good result, 4 had medial-lateral pin fixation while 2 had 2-lateral pin fixation. There were only 3 patients in whom the result was rated as fair: 2 had medial-lateral pin fixation and one had 2-lateral pin fixation. Of the 3 patients rated as poor, one was treated with medial-lateral pin fixation while 2 had undergone 2-lateral pin fixation.

The mean loss in elbow extension in patients treated with medial-lateral pin fixation was 7.14° (range, 2.11°–16.39°), while that in patients treated with 2-lateral pin fixation was 7.11° (range, 3.69°–17.91°) [Table 5]. The mean loss in elbow flexion in patients treated with medial-lateral fixation was 8.68° (range, 0.04°–17.32°), while that in patients treated with 2-lateral pin fixation was 11.26° (range, 0.86°–21.66°) [Table 6].

Analyses with Student *t* test of the carrying-angle loss, elbow extension loss, and elbow flexion loss indicated that there was no significant difference in these parameters between patients who had medial-lateral pin fixation and those who had 2-lateral pin fixation (Table 7).

The Baumann angle loss and MEE angle loss were measured in 54 patients. In the remaining 10-year-old patient, the capitellum and medial epicondylar epiphyses had already fused at follow-up, thus the Baumann angle and the MEE angle could not be measured. The mean Baumann angle loss in the medial-lateral pin fixation group and the 2-lateral pin fixation group was 5.96° and 5.30°, respectively. The mean MEE angle loss in the medial-lateral pin fixation group and the 2-lateral pin fixation group was 6.07° and 6.93°, respectively. Analyses of both the Baumann angle loss and the MEE angle loss using Student *t* test showed no significant difference between medial-lateral pin fixation and 2-lateral pin fixation (Table 8).

Two (of all 66 patients) neurologic deficits were diagnosed on admission. One patient had ulnar nerve palsy while the other had partial median nerve injury. Of the 55 patients available for outcome evaluation, 7 ulnar nerve injuries (5 patients in the medial-lateral fixation group and 2 patients in the 2-lateral pin fixation group) and one radial nerve injury (a patient in the 2-lateral pin fixation group) were detected after the treatment procedure. These patients were followed up 6-weekly in the clinic, and all of them recovered completely within 6 months after the surgery.

The iatrogenic ulnar nerve injury between the medial-lateral pin fixation group and the 2-lateral pin fixation group was further analysed using the crossed table method and Fisher's exact test. The p value was 0.428. Hence, there was no significant difference in the incidence of ulnar nerve injury between the two groups of patients.

The treatment of 3 patients was complicated by pin tract infection. Two of the patients were treated with medial-lateral pin fixation, and both had grade I infection. One patient treated with 2-lateral pin fixation had grade II infection. For these 3 patients, following the removal of the affected pins, oral Cloxacillin 50 mg/kg was administered 6-hourly for one week. They all recovered at the subsequent follow-up. No vascular injury or deficit that required exploration was encountered. All patients with absence of radial pulse after injury have good capillary refilling of the fingers and the radial pulse eventually reappeared after surgery. There was no case of compartment syndrome or Volkmann ischaemic contracture on the last clinical review.

DISCUSSION

The mean follow-up duration of the 55 patients was 8.93 months (range, 3.13–14.73 months). All of them regained their full range of elbow motion that indicated full recovery from joint stiffness. Abnormal flexion or extension at this stage would reflect malunion of the fracture in the sagittal plane. Several patients achieved full elbow motion on the second follow-up or 6 weeks after the cast was removed. This explained the follow-up duration of less than 4 months in some cases. In this study, the displacement after 2 methods of fixation were compared, and hence the long-term outcome of the elbow where the remodelling process may play a significant role was not studied. Malunion in the coronal plane was assessed both clinically by measuring the carrying angle at last follow-up and radiologically by measuring the Baumann and MEE angles at 9 weeks after treatment.

Based on these clinical and radiological parameters, we were not able to find any difference in the change of coronal and sagittal plane alignments of the distal fragment after treatment with the 2 methods of pin fixation. All patients had their reduction performed under the guidance of an image intensifier. Only satisfactory reduction based on carrying angle and Baumann angle assessed on the table were accepted. Since the enrolment of both groups was randomised, and the standard protocol of reduction was applied for both groups, we considered the change of alignment in any plane at the end of the study period was due to loss of reduction during healing process in the cast. In other words, they reflect the stability of fixation in clinical setting. Therefore, we can consider that there was no difference in the stability of fixation provided by either the medial-lateral pin fixation or 2-lateral pin fixation.

There were 6 patients with a carrying-angle loss of 10^{o} or more compared to the opposite elbow. These patients had either a reduced carrying angle or had developed cubitus varus deformity. Three of the patients were treated with medial-lateral pin fixation, and the other 3 with 2-lateral pin fixation. The cubitus varus may need to be corrected—not only for cosmetic appearance, but also to avoid tardy posterolateral rotatory instability of the elbow in future.[10] Posterolateral rotatory instability is a 3-dimensional kinematical disturbance of elbow motion in which the radius and ulna subluxate with respect to the distal part of the humerus, such that the forearm bones displace into external rotation and valgus during flexion of the elbow. This instability pattern is secondary to deficiency of the ulnar part of the lateral collateral ligament.

Malunion in the sagittal plane rarely requires surgical correction. A moderate degree of deformity in this plane would not cause any functional disability as described earlier. Moreover, we could expect further improvement over time due to remodelling of the bone.

We looked into injuries of the ulnar and radial nerves separately in order to correlate the mechanism of injuries with the procedures of wire fixation. Five patients with iatrogenic ulnar nerve injuries were treated with medial-lateral pin fixation while 2 patients with a similar injury were treated with 2-lateral pin fixation. Analyses using the crossed table method and Fisher's exact test yielded a p value of 0.24. Therefore, there was no statistical difference in the incidence of iatrogenic ulnar nerve injury between the two methods of fixation. Although medial-lateral pin fixation produced more than twice the incidence of iatrogenic ulnar nerve injury as compared to 2-lateral pin fixation, this observation could show a trend that could only be verified with a larger sample size. There was only one iatrogenic radial nerve injury in the 2-lateral pin fixation. The value is too small to be analysed.

Iatrogenic nerve injuries in this study were most likely neuropraxia or axonotmesis (Sunderland type 1 and 2) since all of them recovered without exploration or repair within 6 months after index procedure. Injury to the ulnar nerve could be due to local irritation or pressure from the medial pin especially during insertion. Complete transection of the nerve or neurotmesis was very uncommon.[11] Injury by the medial pin, however, could not explain ulnar nerve deficits in patients who were treated with 2-lateral pin fixation. It was possible that the pin was not the only cause of nerve injury in the process of treatment. Mobility of ulnar nerve at the elbow joint is very limited compared to the median and radial nerve. The ulnar nerve is closely related to the posterior surface of the medial epicondyle. Proximally, its mobility might be limited by arcade of Struthers, while just below the elbow joint it goes between the 2 origins of flexor carpi ulnaris. During the process of closed manipulation, acute axial distraction was applied before attempting reduction. The elbow was then hyperflexed to reduce the distal fragment that was usually displaced in extension. Occasionally, direct pressure on the olecranon process was applied to achieve this objective. Excessive axial distraction of the fracture site as well as over-correction of the distal fragment into hyperflexion during manipulation might potentially cause excessive stretching of the ulnar nerve. This might explain the 2 cases of ulnar nerve deficit when fracture fixation was performed by 2-lateral pin fixation.

Absence of radial or ulnar pulse was not considered an indication for exploration in our protocol.[12] All our patients had good nail or pulp perfusion, and in all the patients these findings were maintained throughout the period of traction, manipulation, pin fixation, and plaster of Paris casting. None of the patients in our series developed evidence of ischaemic contracture to suggest muscle necrosis at follow-up. All patients were put on axial skin traction with elbow extended while waiting for operation. This straight lateral skin traction device was similar to the one described by Piggot et al.,[13] although they used it as a method of conservative treatment to all their patients with supracondylar fractures. In this series, we only used this traction until the patients were called to the operation room. Straight lateral skin traction reduced the pressure in cubital fossa by allowing its contents to occupy a greater volume. We believe that this type of traction might have helped to maintain the distal circulation during the process of treatment.

CONCLUSION

From this prospective study, we conclude that there is no significant difference in the stability provided by medial-lateral pin fixation and 2-lateral pin fixation in both coronal and sagittal planes. There is also no significant difference in the incidence of ulnar nerve injuries between the 2 methods of fixation, although there is a trend to suggest that more injury occurred in the medial-lateral pin fixation group. The lateral skin traction is a safe and effective method to immobilise the elbow before surgical treatment and it may contribute to the low rate of vascular complications.

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