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The functional outcome of displaced supracondylar fracture humerus in children treated by open reduction and internal fixation by lateral pins compared to medial and lateral pins: A prospective study

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Abstract
Introduction: Supracondylar fracture of humerus in children is one of the most common fractures seen in Orthopaedic department all over the world accounting for 50 – 70% of all elbow fractures in children in the first decade of life [1]. Traditionally this type of fracture is associated with high rates of malunion, nerve injury and vascular complications. Cross pinning has been presumed to be more stable but it can cause iatrogenic ulnar nerve injuries. Therefore this study was conducted to compare whether lateral pin construct if placed properly can provide the same stability like medial and lateral pinning, at the same time avoiding the possibility of iatrogenic ulnar nerve injury.
Aims and Objectives: To evaluate whether lateral pin fixation provides the same functional outcome compared to medial and lateral pin fixation and to assess whether chances of iatrogenic ulnar nerve injury was more in medial and lateral pin fixation than lateral pin fixation alone.
Materials and methods: All patients between 3 – 12 of age who had sustained Type III Gartland supracondylar humeral fractures who satisfied the inclusion criteria coming to Orthopaedics OPD/casualty were assessed both clinically and radiologically. Patients were randomly selected by drawing lots with even numbers included in Group A (lateral entry) and odd number in Group B (medial and lateral entry). In all cases a posterior approach and triceps splitting method was used. A neurovascular examination was done preoperatively and in the immediate post-operative period. All the patients were evaluated clinically and radiologically in the immediate post operative period followed by examination at 1 week, 4 weeks, 3 months and 6 months. The final grading was decided by putting the values of the three parameters considered in the Modified Flynn's Criteria in the final scoring system
Results and discussion: In this study in group A 21 patients had Excellent, 6 patients had Good, 3 patients Fair and one patient had Poor results. In group B 20 patients had Excellent, 5 patients Good, 3 patients Fair and one patient had Poor outcomes. The results of this study were comparable to a similar study done by Yi Meng Yen and Mininder S Kocher [9] although the study used closed reduction and percutaneous pinning as the procedure.
Conclusions: From this prospective study we conclude that there is no significant difference between the stability and functional outcome provided by the medial and lateral pin fixation and two lateral pin fixation methods. But the medial and lateral pinning group shows one case of iatrogenic ulnar nerve injury. Therefore, the lateral pin fixation method for the treatment of Type III supracondylar fractures of humerus in children is a reliably safe method to avoid iatrogenic ulnar nerve injury which also provides adequate stability if the proper pin fixation principles are used.

Keywords: Functional outcome, displaced supracondylar fracture humerus, children treated, open reduction, internal fixation

Introduction

Supracondylar fracture of humerus in children is one of the most common fractures seen in Orthopaedic department all over the world accounting for 50 – 70% of all elbow fractures in children in the first decade of life [1]. Traditionally this type of fracture is associated with high rates of malunion, nerve injury and vascular complications.

Current method of treatment of supracondylar fracture of humerus in children is based on Gartland classification. Flynn *et al.* reported the incidence of cubitus varus deformity after the treatment of this fracture was 5% where as Arino *et al.* reported it as almost 21% [2, 3].

Various treatment methods has been described for type III supracondylar fracture such as closed reduction & long arm slab, Dunlop skin traction, Olecranon traction but all these have significantly large complication rates. The standard method of treatment has been closed reduction and pin fixation. Open reduction and internal fixation is indicated irreducible fractures, open fractures, ischemic hand not revascularising with reduction and failure of closed reduction. These methods have given excellent results reported by various authors. However controversy persists regarding satisfactory technique in terms of stability and iatrogenic ulnar nerve injury. Ideally medial and lateral pin method engage medial and lateral column at the fracture site whereas lateral pin technique stabilizes lateral and central column. Cross pinning has been presumed to be more stable but it can cause iatrogenic ulnar nerve injuries. Therefore this study was conducted to compare whether lateral pin construct if placed properly can provide the same stability like medial and lateral pinning, at the same time avoiding the possibility of iatrogenic ulnar nerve injury.

Aims and Objectives: To evaluate whether lateral pin fixation provides the same functional outcome compared to medial and lateral pin fixation and to assess whether chances of iatrogenic ulnar nerve injury was more in medial and lateral pin fixation than lateral pin fixation alone.

Materials and Methods:
Study Design: Prospective randomized study
Period of Study: July 2011 to October 2012
Study Setting: Department of Orthopaedics, Government Medical College, Kottayam Study Population: Patients between 3 – 12 years of age with Type III supracondylar fracture of humerus coming to Orthopaedics OPD/casualty in the study period Sample Size: 60 patients with 30 patients in each group Inclusion Criteria: The patients fulfilling the following inclusion criteria were included in the study: Age between 3 – 12 years, those presented within 4 days, no previous fracture in the same elbow, Gartl and Type III fractures

Exclusion Criteria: The patients fulfilling the following exclusion criteria were not included in the study: Inability to perform neurological evaluation, Floating elbow.

Funding Agency: Nil
Statistical Analysis:
Data was entered in excel software and analysis were done using SPSS version 16 and MATLAB software. Flexion, extension and range of movements of the affected elbow were measured at 3 months and 6 months and the comparison was done using Paired t test. All comparisons (including functional outcome) between the two groups i.e. lateral pinning and medial and lateral pinning was done by calculating the p value using Pearson Chi Square test.
60 patients included in this study were divided into two groups. Group A (medial and lateral pinning) consisted of 31 patients and Group B(lateral pinning) consisted of 29 patients. The data was collected using a proforma. The results were analysed at the end of the study and observations were made.

Study Procedure
All patients between 3 – 12 of age who had sustained Type III Gartland supracondylar humeral fractures who satisfied the inclusion criteria coming to Orthopaedics OPD/casualty were assessed both clinically and radiologically. Patients were admitted, informed consent was obtained, the affected limb was immobilized with arm slab in 35 – 4O degrees flexion and the surgery was done. Patients were randomly selected by drawing lots with even numbers included in Group A (lateral entry) and odd number in Group B (medial and lateral entry). All the surgeries were done under GA. In all cases a posterior approach and triceps splitting method was used. A neurovascular examination was done preoperatively and in the immediate post-operative period. All the patients were evaluated clinically and radiologically in the immediate post operative period followed by examination at 1 week, 4 weeks, 3 months and 6 months. In both groups K wires were removed at 4 weeks and active mobilization exercises were started. Clinical evaluation included passive range of movements, measurement of carrying angle, neurovascular status, and any evidence of superficial and deep infection.
Clinical evaluation was graded according to carrying angle and elbow range of motion measured at 3 months and 6 months using criteria of Flynn *et al*. Radiological examination included calculation of Bauman's angle and Humero capitellar angle on the immediate radiographs and 6 months radiographs and the values were recorded. The final grading was decided by putting the values of the three parameters considered in the Modified Flynn's Criteria in the final scoring system, i.e. – loss of carrying angle, loss of flexion and loss of extension. These values were calculated at 6 months by comparing the values with the contralateral normal elbow.
Modified Flynn's Criteria:

Results	Rating	Carrying angle loss (in degrees)	Loss of flexion (in degrees)	Loss of extension (in degrees)
Satisfactory	Excellent	O -4.9	O – 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

The lower of the three grades will be adopted as the overall grade.

The study was confined to the guidelines of declaration of Helsinki 1964 revised in 1975. The study was subjected to ethical review board of the study. His/her right to opt out of the study without prior notice was explained and written consent was obtained from the patient first degree relatives for his/her inclusion in the study.

Results
The groups A and B were comparable in terms of prefracture characteristics, fracture patterns, post reduction radiographic and clinical measurements. During the study period 66 patients were treated for completely displaced supracondylar fractures of humerus in children. Six patients were excluded from the study due to loss of follow up and study was done with 60 patients. Group A (cross entry) comprised of 31 patients and Group B (lateral entry) comprised of 29 patients.

Age Distribution
Of the 60 patients included in the study most of the patients were between the age group 9 – 12 years (38.3%). 35% of the patients were between 3 – 6 years and 26.7% patients were between 6 – 9 years.

Table 1: Age distribution

	Age group	Frequency	Percentage
1	3-6 years	21	35.0
2	6-9years	16	26.7
3	9-12years	23	38.3
	Total	60	100.0

Table 2: Age Distribution in Group A and B

		Age Class			Total
		3-6	6-9	9-12	
Procedure	Cross Pinning	10	9	12	31
	Lateral Pinning	11	7	11	29
Total		21	16	23	60

The mean age in group A was 7.79(SD_2.91) and \group B was 7.44 (SD_2.76).

Table 3: Mean age distribution in the two groups.

		Age	
		Mean	Std. Deviation
Cluster	Group A	7.7903	2.91197
	Group B	7.4483	2.76569
	Combined	7.6250	2.82337

Sex Distribution

Majority of the patients in the study group were males (70%). This sex predilection may be due to the more agile nature of boys.

Table 4: Sex distribution:

	Sex	Frequency	Percent
1.	Male	42	70.0
2.	Female	18	30.0
	Total	60	100.0

Table 5: Sex distribution in the two groups

		Sex		Total
		Male	Female	
Procedure	Cross Pinning	20	11	31
	Lateral Pinning	22	7	29
Total		42	18	60

Mechanism of Injury

Majority of the patients (91.7%) sustained injury following fall, while 3.3% patients had injury following road traffic accidents and 5% sustained their injuries by other means (assault, hit by objects).

Table 6: Mechanism of injury

	Mechanism of injury	Frequency	Percent
1.	Fall	55	91.7
2.	Road Traffic Accident	2	3.3
3.	Others	3	5.0
	Total	60	100.0

Table 7: Mechanism of injury in the two groups

		Mechanism of Injury			Total
		Fall	Road Traffic Accident	Others	
Procedure	Cross Pinning	29	1	1	31
	Lateral Pinning	26	1	2	29
Total		55	2	3	60

Side of Injury

63.3% of the patients sustained their injuries in the right upper limb and 36.7% on left. This difference may be due to the prominent right hand dominance in the community.

Table 8: Side of Injury

	Side	Frequency	Percent
1	Right	38	63.3
2	Left	22	36.7
	Total	60	100.0

Table 9: Side of Injury in two Groups

		Side		Total
		Right	Left	
Procedure	Cross Pinning	20	11	31
	Lateral Pinning	18	11	29
Total		38	22	60

Type of Fracture

In a study by Wilkins *et al.* the incidence of extension type supracondylar fractures was reported as 97.7% and that of flexion type as 2.2%. In this study the incidence of extension type of supracondylar fractures was 93.3% and the rest were flexion type.

Table 10: Type of fracture

	Type	Frequency	Percent
1	Extension Type	56	93.3
2	Flexion Type	4	6.7
	Total	60	100.0

Table 11: Type of fracture in the two groups

		Type	
		Extension Type	Flexion Type
Procedure	Cross Pinning	29	2
	Lateral Pinning	27	2
Total		56	4

Displacement

Displacements in type 3 supracondylar fractures can be either posteromedial or posterolateral based on the shift of the distal fragment. According to western literature posteromedial displacement is more common (75%). The posterolateral type although less common is associated with more neurovascular complications. In this study 73.3% patients had posteromedial displacement and 26.7% patients had posterolateral displacement.

Table 12: Type of displacement

	Displacement	Frequency	Percent
1	Posteromedial	44	73.3
2	Posterolateral	16	26.7
	Total	60	100.0

Table 13: Displacement of fracture in two Groups

		Displacement		Total
		Posteromedial	Posterolateral	
Procedure	Cross Pinning	23	8	31
	Lateral Pinning	21	8	29

Pulseless Viable Hand

All patients were examined for any neurovascular deficit at the time of presentation. 5 patients, 3 in group A and 2 in group B had absent radial and ulnar pulse at the time of presentation.

Doppler study of the affected upper limb was done in all the 5 patients after consulting with Plastic Surgery Department. None of these patients required any exploration and in all patients pulse returned after the fracture fixation. There was no statistically significant difference between the two groups in this regard (p value =. 697)

Table 14: Pulse less viable hand in Group A and B

		Pulseless Viable Hand		Total
		No	Yes	
Procedure	Cross Pinning	28	3	31
	Lateral Pinning	27	2	29
Total		55	5	60

Preoperative Nerve Injury

Preoperatively all the patients were assessed for any nerve injury. Of the 60 patients 3 patients had median nerve injury, 1 patient had radial nerve injury and 1 patient had combined median and radial nerve injury. All the 5 patients proceeded with surgery for fracture fixation and they were observed for recovery. All the patients had recovered at the 6 months follow up and no further intervention was required for this.

Table 15: Pre operative nerve injury in two groups

		Pre Operative Nerve Injury				Total
		Nil	Median Nerve Injury	Radial Nerve Injury	Median and Radial Nerve Injury	
Procedure	Cross Pinning	29	1	0	1	31
	Lateral Pinning	26	2	1	0	29
Total		55	3	1	1	60

Both the groups were comparable in this regard and no significant difference was there (p value=.488).

Concomitant Injuries

As part of the initial clinical assessment other significant injuries were noted. In the study group one patient had radial head fracture, two patients had distal end of radius fractures, one had fracture clavicle and one had fracture shaft of ulna. All the injuries were in the ipsilateral side and all were treated conservatively.

Table 16: Concomitant Injuries in two Groups

		Concomitant Injuries					
		Nil	Radial Head Fracture	Fracture Distal End Radius	Fracture Clavicle	Fracture Shaft of Ulna	Total
Procedure	Cross Pinning	27	0	2	1	1	3
	Lateral Pinning	27	1	1	0	0	2
Total		54	1	3	1	1	60

There was no significant difference between the two groups based on the concomitant injuries (p value =.514).

Post-Operative Nerve Injury

Post operatively all the patients were examined for nerve injuries. Since the chance for ulnar nerve injury is more in case cross pinning all the patients in group A were specifically checked for any ulnar nerve injury. Of the 60 patients operated only one patient had evidence of ulnar nerve injury. This patient was in group A and there was numbness in the ulnar nerve area of the hand and there was clawing. The patient was managed conservatively with observation and the patient recovered completely by 6 months. In all the patients who had preoperative nerve injury the injury persisted in the post operative period. Apart from that there was no cases injury to other nerves.

Table 17: Post-Operative Nerve Injury in Two Groups

		Post Operative Nerve Injury		Total
		Nil	Ulnar Nerve Injury	
Procedure	Cross Pinning	30	1	31
	Lateral Pinning	29	0	29
Total		59	1	60

This result was not statistically significant (p value =.329). According to this study there was no significant difference in the incidence of ulnar nerve injury between the two procedures.

Infection

Every patient was checked for evidence of any infection at 1 week and 3 weeks. Only one case of infection at the incision site was there which was treated by pus culture and sensitivity and appropriate antibiotics. This occurred in the group B and the difference was not a significant one (p value =.297).

Table 18: Infection in Group A and B

		Infection		Total
		Nil	Wound Infection Present	
Procedure	Cross Pinning	31	0	31
	Lateral Pinning	28	1	29
Total		59	1	60

The Baumann's angle was measured for all patients at 6 months follow up. The Baumann's angle is most frequently cited method of assessing fracture reduction and has been reported to correlate well with the final carrying angle. Williamson *et al.* fig found that an average of 72 degrees (64- 81degrees) [4] could be considered as a normal Baumann's angle and as long as the angle did not exceed 81 degrees, cubitus varus could not occur. In the study group the mean Baumann's angle was 73.40 degree. The mean angle in group A was 75.90 degree and in group B was 70.89 degree. 3 patients in group A and 2 patients in group B had Baumann's angle greater than 81 degree. There was no statistically significant difference between two groups based on Baumann's angle measurements as per Pearson Chi Square tests.

Humerocapitellar Angle

The angle formed by the long axis of humerus and the long axis of capitellum should be approximately 40 degrees [5]. In supracondylar fractures with posterior tilting of the distal fragment the angle will diminish, whereas in anterior tilting of the distal fragment it will increase. In the study group the humero capitellar angle was measured at 6 months. The mean humero capitellar angle was 39.48 degree. In group A the mean angle was 38.84 degree and in group B it was 40.13 degree and this difference was insignificant statistically (p value =.643).

Carrying Angle

The carrying angle is the angle formed in between the extended long axis of the arm and long axis of the forearm at the central point of the extended elbow axis. It is measured in the supine and extended position of the forearm. It varies from 10 – 15 degree [6]. Exaggeration of this angle is called cubitus valgus. Reduction, neutralization or reversal of this angle is called cubitus varus [6].

In the study group the mean carrying angle was 10.45 degree. It was 10.16 degree in group A and 10.75 degree in group B. The carrying angle in those extremities with an extension lag was measured at the maximum possible extension.

There was no significant difference between the two groups based on the carrying angle measurements (p value = 577).

Flexion, Extension and Total Range of Movements

All the patients at 3 months and 6 months follow ups were clinically assessed for the flexion, extension and total range of movements of the ipsilateral elbow. As evidenced from previous studies flexion, extension and range of movements of the elbow are important indicators for the functional outcome of supracondylar fractures of the humerus. Normal range of elbow movements is 0 to 145 – 160 degrees [6]. In this study the mean elbow flexion was 127 degrees (SD_6.85) at 3 months and 134.65 degrees (SD_6.38) at 6 months. The mean extension was -3.85 degrees (SD_2.42) at 3 months and -1.53 degrees (SD_1.59) at 6 months. The mean range of movement was 123.45 degrees (SD_7.96) at 3 months and 133.12(SD_7.43) at 6 months. There was an improvement in mean flexion by 7.65 degrees, mean extension by 2.32 degrees and mean range of movements by 9.67 degrees at 6 months compared to that at 3 months. This result was found to be statistically significant (p value < 0.01 by Paired t test).

Table 19: Mean Flexion, Extension and Range of Movements

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Flexion 3M	127.100	60	6.85615	.88513
	Flexion 6M	134.650	60	6.38543	.82436
Pair 2	Extension 3M	-3.850	60	2.42043	.31248
	Extension 6M	-1.5333	60	1.59943	.20649
Pair 3	Total Rom 3M	123.450	60	7.96268	1.02798
	Total Rom 6M	133.117	60	7.43353	.95966

Table 20: Paired Comparison

		N	Correlation	Significance
Pair 1	Flexion 3M and Flexion 6M...	60	.886	.0000078
Pair 2	Extension 3M and Extension 6M...	60	.835	.0000091
Pair 3	Total Rom 3M and Total Rom 6 M...	60	.925	.0000012

There was no significant difference between the two groups based on flexion at 3 months (p value =.420), extension at 3 months (p value =.896), range of movements at 3 months (p value =.238), flexion at 6 months (p value =.774), extension at 6 months (p value =.516) and range of movements at 6 months (p value =.161) between the two groups based on Pearson Chi Square tests.

Loss of Carrying Angle

Loss of carrying angle is a component in grading the functional outcome of elbow as per Modified Flynn's Criteria. This was calculated at the final follow up at 6 months by comparing the difference in carrying angle with the contra lateral elbow. The degrees of carrying angle lost were put in the final grading system and the grades were determined.

The p value determined as per Pearson Chi Square tests was.061 and it failed to show any statistically significant difference between the two groups.

Loss of Flexion and Extension

Both loss of flexion and extension were independent components of the Modified Flynn's Criteria determining the final functional outcome. The degrees of flexion and extension loss were determined clinically compared to the contra lateral normal elbow at 6 months. The values were put in the final grading system.

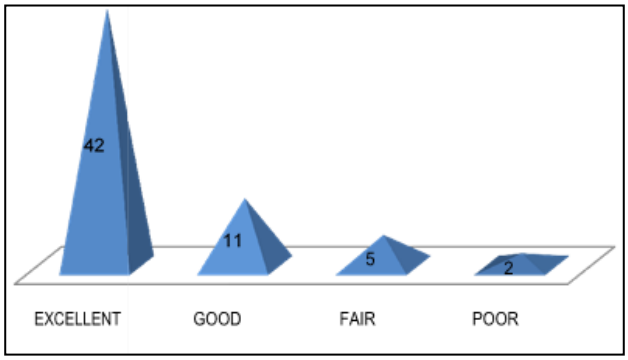
The p value determined as per Pearson Chi Square tests was. 658 for loss of flexion and.182 for loss of extension and both the values were statistically insignificant between the two groups.

Modified Flynn's Criteria Grade

In this study in group A 21 patients had Excellent, 6 patients had Good, 3 patients Fair and one patient had Poor results. In group B 20 patients had Excellent, 5 patients Good, 3 patients Fair and one patient had Poor outcomes.

Table 21: Modified Flynn's Criteria Grades – All Patients

		Frequency	Percent
Valid	Excellent	42	70.0
	Good	11	18.3
	Fair	5	8.3
	Poor	2	3.3
	Total	60	100.0



Graph 1: Modified Flynn's Criteria Grades, All Patients

The p value as per Pearson Chi Square tests was 0.974 and accordingly there was no significant difference in functional outcome between the groups. This result was consistent with the previous studies done comparing the functional outcome of the displaced supracondylar fractures in children treated by percutaneous crossed or lateral pinning.

Discussion

Treatment of Type III supracondylar fractures of humerus in children by closed reduction and percutaneous pinning has yielded satisfactory results as supported by literature. Open reduction and pinning is indicated in ischemic hand that does not revascularise with reduction of the fracture, an open fracture, an irreducible fracture and inability to achieve a satisfactory reduction by closed method. Also open reduction will be required in many parts of the world where the facility of intraoperative radiography is not available in the emergency department.

Controversy persists regarding the adequate pin fixation technique comparing lateral pin fixation with medial and lateral pin fixation. In this study no significant difference between both fixation methods in terms of stability and functional outcome was found, but there was evidence of iatrogenic ulnar nerve injury (0.03%) in the medial and lateral pinning group.

The medial and lateral pinning method is supposed to have the advantage of better fracture stability, although iatrogenic ulnar nerve injury can occur with this technique. Conversely lateral pin entry has the advantage of avoiding ulnar nerve injury but this construct has been thought to be biomechanically less stable.

A cadaveric study reported by Lee SS *et al.* [7] and Zionts *et al.* [8] suggested that medial and lateral entry provides greater torsional rigidity than lateral entry pin fixation does. The overall strength of this construct is not only related to pin entry but mainly to divergence of the pins in different column and number of pins. The greater strength seen with divergence of the pins was related to the location of interaction of the two pins and the fact that the greater amount of divergence between the two pins allow for some purchase in the medial and lateral column. Bloom *et al*. reported that three lateral divergent pins were equivalent to cross pin fixation and both of these constructs were stronger than two lateral divergent pins.

Although the incidence of iatrogenic ulnar nerve injury is 0.03% in the medial and lateral entry group in this study, there is always a risk of ulnar nerve injury with this procedure. There fore one obvious conclusion is that if medial pinning is used, the lateral pin should be used first followed by medial pin fixation with elbow in extension. But the best way to avoid ulnar nerve injury is not to place medial pin. This study also substantiates the fact that the lateral pinning method if properly done provides the same stability as the medial and lateral pinning.

Although closed reduction and percutaneous pinning is the gold standard treatment recommended for the treatment of supracondylar fractures in children open reduction and pinning was the procedure used in this study. This was because of the lack of intraoperative radiography in the emergency department. Also this fracture required an emergency surgery so the percutaneous pinning is not advised as an elective procedure. So we had to go with emergency open reduction and internal fixation with k wires as the treatment of these fractures. This study gains its importance by the fact that many centres in our country may not be having intraoperative radiography in the emergency department; still the fracture requires to be fixed on an emergency basis. Also open reduction may be required if closed reduction fails.

Infection, elbow stiffness, myossitis ossificans were the expected complications with the open reduction technique. At the end of the study we found only one case of wound infection which was cured by Pus culture and sensitivity and appropriate antibiotics. All patients acquired considerable range of movement by 6 months. The mean elbow range of motion was 133.12 degrees (SD_7.43). This was expected to improve on subsequent follow ups. Also there was no evidence of myossitis ossificans in any patient at the end of 6 months, both clinically and radiologically.

The results of this study were comparable to a similar study done by Yi Meng Yen and Mininder S Kocher [9] although the study used closed reduction and percutaneous pinning as the procedure.

Conclusions

From this prospective study we conclude that there is no significant difference between the stability and functional outcome provided by the medial and lateral pin fixation and two lateral pin fixation methods. But the medial and lateral pinning group shows one case of iatrogenic ulnar nerve injury. Therefore, the lateral pin fixation method for the treatment of Type III supracondylar fractures of humerus in children is a reliably safe method to avoid iatrogenic ulnar nerve injury which also provides adequate stability if the proper pin fixation principles are used.

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