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## Functional outcome of carrying angle changes following supracondylar humeral fractures in children

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### Abstract

**Background:** The carrying angle (CA) is the angle created when the long axis of the humerus and the long axis of the stretched supinated forearm intersect. It disappears when the elbow is pronated and flexed. The aim of this work was to study changes of CA of the elbow after supracondylar humeral fractures in children as compared to the unaffected side and assess the functional outcomes related to these possible changes.

**Methods:** This retrospective-prospective study was conducted on 21 children aged more than 5 years to 12 years old, having supracondylar humeral closed fractures within one week from the injury and treated by closed reduction and fixed by two percutaneous K-wires applied from the lateral side, had a change of the elbow CA compared to the other side at the end of minimum follow up period (twelve months after fixation of the fracture).

**Results:** As stated by Flynn's criteria for grading, all cases achieved satisfactory outcomes, 16 patients had excellent outcomes, 4 patients had good outcomes and one patient had fair outcomes, whereas no cases were graded as unsatisfactory outcomes. All parents were totally satisfied with the results, only three patients had a minimal degree of dull pain that just appears when lifting heavy objects, and one case of pin tract infection that was resolved on oral antibiotics.

**Conclusions:** The CA changes following supracondylar humeral fractures managed by closed reduction and K-wires fixation are resulting in satisfactory outcomes represented in good functional outcomes, few complications were reported; they weren't severe and didn't affect the daily living activities of patients.

**Keywords:** Functional outcome, carrying angle changes, supracondylar, humeral fractures, children

### Introduction

The carrying angle (CA) of the human elbow joint is the angle produced between the long axis of the arm and forearm in the coronal plane when the forearm is completely extended and supinated. CA reflects the valgus deviation of the forearm in the anatomical position. This angle vanishes at elbow flexion and upon forearm pronation. It might alter as the skeleton grows<sup>[1]</sup>.

Normally forearm is aligned in valgus relative to the arm ranging between 5 and 10 degrees in boys and between 10 and 15 degrees in girls. The CA is crucial in weight carrying and aids in preventing contact with the hip and lower limb. It enables the hand to be placed directly above the middle of the object being carried, creating a comfortable lever arm.

Changes to the carrying angle could either be an exaggeration known as Cubitus valgus, where the forearm is slanted away from the body more than usual when fully extended, or a change in the carrying angle itself; or disappearance known as Cubitus rectus with neutral alignment and no angulation; or reversal known as Cubitus varus in which there is inward deviation of the forearm towards the midline of the body.

Its existence has been explained by the trochlear notch of the ulna's valgus angulation with respect to its shaft and the medial lip of the trochlea's more distal projection in comparison to the capitulum. As stated by Purkait and Chandra<sup>[2]</sup>. The olecranon-coronoid angle exhibits considerable sex dimorphism and may be one of the contributing factors to the carrying angle's apparent sex difference. Unilateral changes in CA may result from previous trauma like supracondylar fractures or lateral condylar humeral fractures or physical growth changes.

The supracondylar humeral fracture malreduction is among the most widespread causes. That produces changes in the elbow carrying angle (reversal, loss or increase). This may result in some functional limitations and possible sequelae such as cosmetic deformity, possible changes in the elbow range of motion or in elbow joint stability. It may affect hand power and performance in carrying objects, especially in the dominant hand. Affection of the ulnar nerve as stretching, recurrent nerve dislocation, and hypermobility causing delayed ulnar neuropathy can follow CA changes after supracondylar humeral fractures<sup>[3]</sup>.

It has long been assumed that changes in CA are compatible with good functional outcomes of the elbow. It is worth studying this assumption and defining the degree of acceptable changes.

The aim of this work was to study changes of the carrying angle of the elbow after supracondylar humeral fractures in children as compared to the unaffected side and assess the functional outcomes related to these possible changes.

### Patients and Methods

This retrospective-prospective study was performed on 21 children aged more than 5 years to 12 years old, having supracondylar humeral closed fractures within one week from the injury and treated by closed reduction and fixed by two percutaneous K-wires applied from the lateral side, had change of elbow carrying angle in contrast to the other side at the end of minimum follow up period (twelve months after fixation of the fracture).

After receiving approval from Tanta University Hospitals' Ethical Committee, the study was carried out. From October 2019 till October 2020, Family members of the patients provided signed, fully informed consent. Exclusion criteria were patients younger than 5 years and older than 12 years of age, neglected cases more than 7 days, Gartland type-I cases, irreducible fractures that necessitated open reduction, any other ipsilateral upper limb injury, open fracture, neurological and or vascular injuries.

All patients were subjected to clinical assessment, physical examination, and radiological evaluation.

All patients had treatment utilizing a closed reduction and two Kirschner wires inserted from the side. The approach was standardized with regard to the pin's position, size (1.6 mm–2 mm), stability on the table, elbow posture during lateral pin placement, and postoperative course. Because the patient's elbow was so little, it was suitable for surgery to place the wounded elbow on an image intensifier plate.

The technique of reduction: Closed reduction was completed and verified with an image intensifier. Manual traction was used to reduce the fracture, and the medial and lateral humeral epicondyles were used to restrict the fracture's rotation while the elbow was bent at 20 degrees. The fracture was then locked in place by pronation of the forearm during flexion. Reduction acceptability was confirmed by the achievement of a normal Baumann angle on the AP view and normal anterior humeral line on the lateral view and two oblique planes to observe the medial and lateral columns under the image intensifier then, The initial K-wire is positioned against the lateral condyle without piercing the skin for fixation, and the starting point is verified under anteroposterior fluoroscopic guidance (the centre of lateral condyle). Before starting the drill, press the wire into the cartilage through the skin for optimal control. The pin is aimed 35° upwards and 10° posterior, and then the second K-wire is placed parallel, divergent or convergent to the first one and engages both

medial and lateral columns. Pins should cross 1-2 cm proximal to the fracture at an angle of about 30° to the humeral shaft to engage sufficient bone in proximal and distal fragments, the reduction, the radial pulse and its quality, carrying angle are again checked.

Depending on oedema and neurovascular condition, the elbow was immobilized with a posterior above-elbow splint with the elbow bent in a range of 70 to 90 degrees. K-wires (1.6 mm to 2 mm) and a Key were also utilized. Post-operative care and immobilization: For all patients we provided parenteral broad-spectrum antibiotics (Cephalosporins) started before the surgery and ended 48 hours after the surgery followed by oral antibiotics (Amoxicillin/clavulanic acid) one week postoperatively. Patients were observed for a pulse, vascular perfusion and hand swelling to exclude compartment syndrome.

Post-operative radiographs (AP & lateral & oblique views) were obtained to check fracture reduction and the position of the wires.

The first postoperative visit usually was 1 week after surgery for assessment of fracture stability and pin configuration through radiographs.

Pins were taken out about 3 weeks postoperatively when radiological healing was noticed. The period of immobilization was about 4 to 5 weeks postoperatively then the slab was removed with an x-ray evaluation to ensure stability.

Following the removal of the last pin, a final follow-up appointment was often made three to four weeks later. If there was a normal range of motion and no pain, the child was free to resume all activities and sports without any limitations.

Methods of assessment of results and rating of outcome: With the arm fully extended and supinated, two lines were made; the first one between the midpoint of the head of the humerus (or the acromion) and the midpoint of the cubital fossa and the second one between the last point and midpoint of the wrist. A goniometer is used with its proximal arm aligned with the first line and its distal arm aligned with the second line. The resultant angle is the carrying angle this method was performed on both sides and the change between them was recorded.

Radiologically: Measured with a manual goniometer between a line passing through the mid-axis of the lower third of the humerus and another line along the mid-axis of the upper third of the forearm between the radius and ulna, passing through the superior radio-ulnar joint on the anteroposterior view. As previously noted, the two lines were stretched to meet at the centre of the Trans-Epicondylar Distance (TECD). On both sides, this was done, and the difference between them was recorded.

Range of motion: Degrees of elbow flexion and extension were measured on both sides and any change was recorded using [Zero, 0-5, 5-10, 10-15, > 15 degrees] pattern.

The stability of the elbow joint was assessed using Varus, Valgus stress, and Lateral Pivot Shift tests and compared to the healthy side. Muscle power was assessed by active flexion-extension of the elbow against resistance. Hand power and grip strength were measured using a handheld dynamometer. Any change between both hands was recorded.

Assessment of the ulnar nerve functions: The elbow flexion test is used to check for symptoms of cubital tunnel syndrome, the patient is asked to fully flex the elbow, supinate the forearm, and extend the wrist; Results are considered favourable if the discomfort returns or if paresthesia develops within two to three minutes. Clinical evaluation was graded utilizing the criteria of Flynn, *et al.*

(57) depending on carrying angle change and elbow range of flexion-extension motion loss as excellent = 0-5, good > 5-10, fair => 10-15, poor => 15.

**Statistical analysis**

The SPSS v26 statistical analysis program was utilized (IBM Inc., Chicago, IL, USA). Mean and standard deviation were employed to present quantitative variables (SD). Frequency and percentages (%) were employed to depict qualitative variables.

**Results**

Patients' demographics, fracture type and displacement are exhibited in Table 1.

**Table 1:** Demographics, fracture type and displacement among the studied patients

Parameters		Mean ± SD / Range N / (%)
Age (years)		6.81 ± 1.60
Sex	Boy	12 (57.14%)
	Girl	9 (42.86%)
Side of the arm	Right hand	13 (61.90%)
	Left hand	8 (38.10%)
Dominant hand	Right-handed	21 (100.0%)
	Left-handed	0 (0.0%)
Type of fracture	Extension Type	19 (90.48%)
	Flexion Type	2 (9.52%)
Mechanism of injury	FOOSH at ground level	19 (90.48%)
	FOOSH from a height	2 (9.52%)

Data are displayed as Mean ± SD or frequency (%).

Surgical fixation and operative time, splint duration and post-operative pin removal among the studied patients are shown in Table 2.

**Table 2:** Surgical fixation and operative time, splint duration and post-operative pin removal among the studied patients

		Mean ± SD / Range N / (%)
Time of surgical fixation	First day of fracture	12 (57.14%)
	On the second day of the fracture	8 (38.10%)
	On the third day of the fracture	1 (4.76%)
Operative time (min)		54.52 ± 6.87
Splint duration (weeks)		4.10 ± 0.44
Time of post-operative pin removal (weeks)		2.62 ± 0.50

Data are displayed as mean ± SD or frequency (%).

Elbow changes among the studied patients are shown in Table 3.

**Table 3:** Elbow changes among the studied patients compared to the opposite side

		N / (%)
Carrying angle change (degree)	> 0-5 degree	17 (80.95%)
	> 5-10 degree	3 (14.29%)
	> 10-15 degree	1 (4.76%)
Elbow flexion change (degree)	0 degree	1 (4.76%)
	> 0-5 degree	16 (76.19%)
	> 5-10 degree	4 (19.05%)
Elbow extension change (degree)	0 degree	4 (19.05%)
	> 0-5 degree	15 (71.43%)
	> 5-10 degree	2 (9.52%)

Data are presented as frequency (%).

There was no difference between both hands when using the hand-held dynamometer in all cases; all parents were totally satisfied with the results. The pain wasn't recorded in all patients either at rest or in motion; only three (14.29%) patients occasionally had a minimal degree of dull pain that just appears when lifting heavy objects. There was one case of pin tract infection that resolved on oral antibiotics. The elbow joint was stable in all patients.

**Table 4:** Post-operative complications among the studied patients

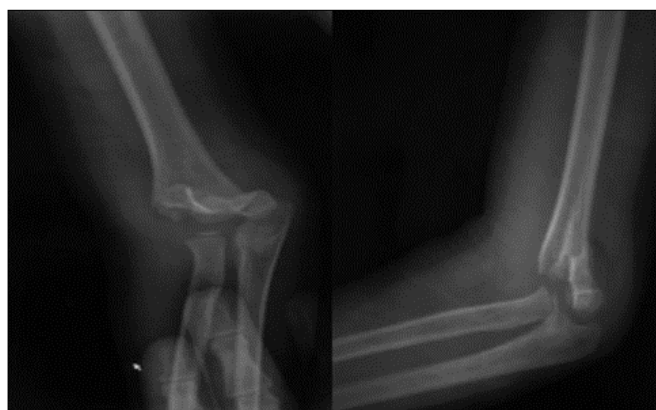
		N / (%)
Pain	When lifting heavy objects	3 (14.29%)
	None	18 (85.71%)
Pin tract infection		1 (4.74%)
Pin migration		0 (0.00%)
Ulnar nerve affection		0 (0.00%)
Elbow joint stability	Stable	21 (100%)
	Unstable	0 (0.0%)

Data are presented as frequency (%).

**Case 1**

Female patient 6 years old, fall on outstretched hand, extension type III supracondylar right (dominant) humeral fracture, managed by closed reduction and two lateral divergent k-wires fixation in the same day of injury, final follow up shows Increase of Carrying angle of the injured elbow compared to the normal side by 3 degrees valgus angulation (regarding the radiological measurement), elbow flexion & extension change between the normal and the injured elbow about (> 0-5) degrees .

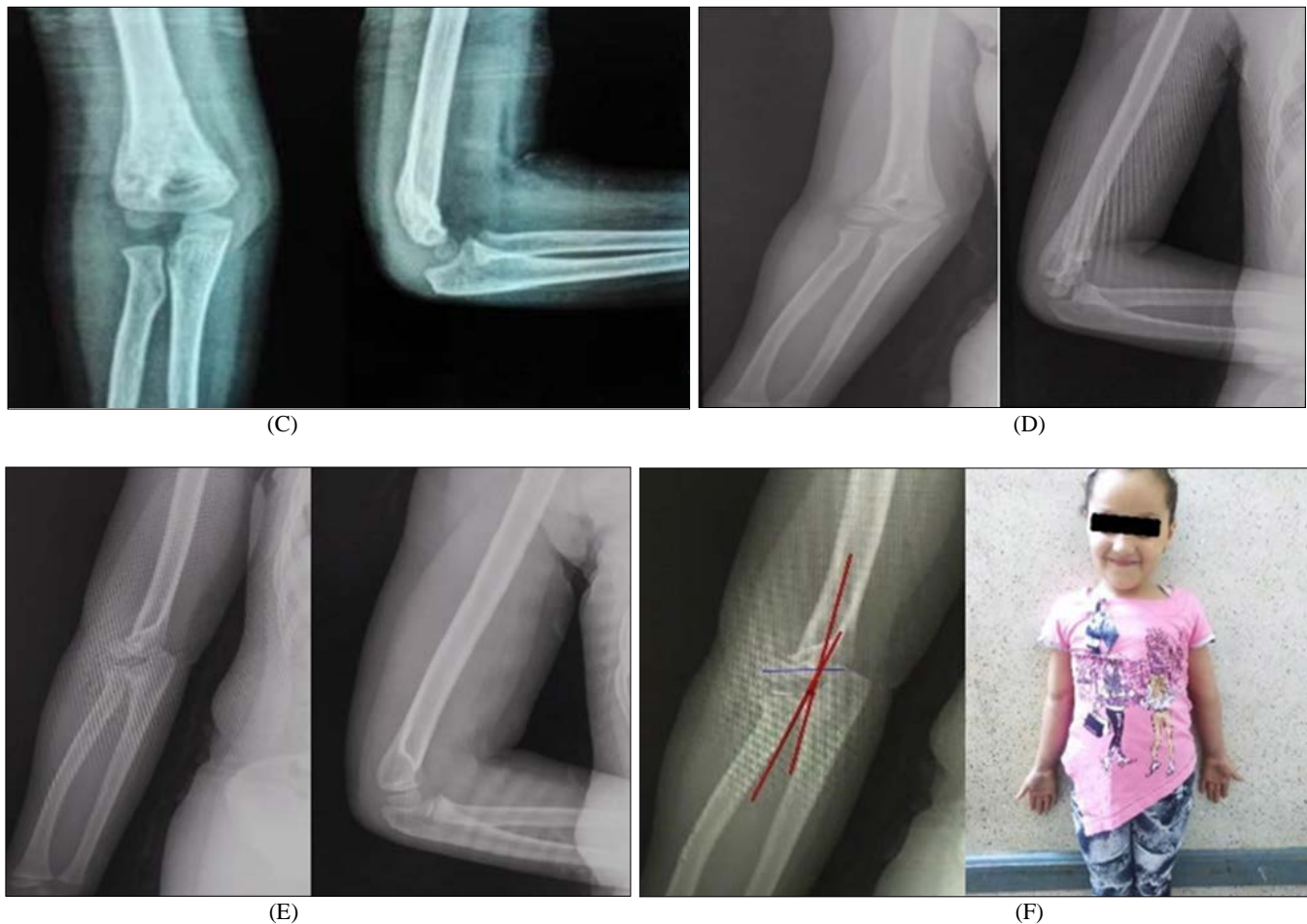
According to Flynn's criteria for grading, she achieved an excellent satisfactory results and her parents were totally satisfied about the results, stable Elbow joint in all movements and no ulnar nerve affection happened, with normal muscle power and hand grip strength in relation to the other uninjured side. Figure 1.



(A)



(B)



**Fig 1:** (A, B) Pre-reduction, (C) 3 months, (D) 6 months, (E) 12 months follow-up x-ray AP and lateral views. (F) carrying angle alignment & measurement

## Discussion

Fractures among children gain special attention due to the considerable growth potential and remodelling capacity of bones at this age<sup>[4]</sup>.

The mean age of patients was  $6.81 \pm 1.6$  years, and all of the patients were right-handed. The study showed male dominance and supracondylar fractures are more predominant among pediatric males. Similarly, Ucar, *et al.*<sup>[5]</sup> found that males were more predominant.

In the present study the most affected arm was the dominant arm (right arm), in contrast to these findings, Baidoo, *et al.*<sup>[6]</sup> in their study demonstrated that the non-dominant arm (left) was the most injured.

The current study showed that regarding the fracture types, the extension type was the major type of fracture. The major mechanism of injury-caused fractures was FOOH at ground level.

More than one-half of the patients in the present study had fracture fixation was on the first day of injury. The mean operative time was 55 minutes, the splint duration was 4 weeks, and for pin removal was 2.6 weeks.

In this study, all 21 patients were treated with closed reduction and percutaneous fixation with 2 Kirschner wires from lateral side.

Pretorius, *et al.*<sup>[7]</sup> in 53 pediatric patients with displaced supracondylar fractures treated with closed reduction and plaster back slab. The mean follow-up time was 12 weeks. The study demonstrated that most of the patients had satisfactory results. The study revealed that the strategy used in the treatment resulted in less satisfactory outcomes compared to closed reduction and fixation using Kirschner

wires. In terms of the restoration of the carrying angle, the procedure likewise produced overall satisfactory outcomes, however only 60% of cases matched the entire Flynn criterion.

Sibinski, *et al.*<sup>[8]</sup> there was no difference in the outcomes between the two groups of 131 children who had crossing wires or lateral wires fixed, either clinically or radiologically. Shamma, *et al.*<sup>[9]</sup> Thirty children with supracondylar humerus fractures were treated using the lateral divergent (15 patients) and lateral parallel (15 patients) techniques. It was determined that both techniques produced satisfactory results in all cases and that there was no statistically significant difference between the two groups in terms of the functional outcome.

Ozuturkmen, *et al.*<sup>[10]</sup> have evaluated closed reduction and lateral pin fixation in 39 children with displaced supracondylar fractures of the humerus. They observed that none of the children experienced problems like pinworm infections, myositis ossificans, compartment syndrome, or nerve damage and that the functional and radiological outcomes were all good (100%). Flynn *et al.*<sup>[11]</sup> The fixation pins do not interfere with the distal end of the humerus' ability to grow, according to a sixteen-year long-term research. On long-term follow-up, 98% of the 52 fractures had satisfactory results. There were no Volkmann's contractures observed, and there were only minimal vascular and neurological problems.

As stated by Flynn's criteria for grading, the final outcomes in the present study: All cases achieved satisfactory outcomes 16(76.19%) patients had excellent outcomes, 4(19.05%) patients had good outcomes and 1(4.76%) patients had fair

results whereas no cases were graded as unsatisfactory outcomes.

The low changes in carrying angle, flexion and extension of the elbow reflect good cosmetics and functional outcomes these minor changes were found in patients of the current study.

Changes of carrying angle from the other normal side were varus angulation in (52.38%) of patients while (47.62%) of patients had valgus change. The majority of patients in this study showed changes in carrying angle estimated between > 0-5 degrees of change and > 5-10 degrees of change, respectively; only one patient showed > 10-15 degrees of change in the carrying angle.

Elbow flexion also showed a few changes; most of the patients showed changes estimated between 0-5 degrees, and the same was found regarding elbow extension.

Mehlman, *et al.* [12] according to Flynn's supracondylar rating scale 83% of cases had excellent and good outcomes, 14% had fair outcomes, and 3% had poor outcomes.

Baidoo, *et al.* [6] reported that the majority of pediatric patients 98% with supracondylar humeral fractures showed satisfactory outcomes according to Flynn's criteria also found that Patients' quality of life decreased at the time of injury but restored to normal 6 months later; the current study showed that all parents were satisfied about the outcomes and the performance of daily activities like (comb hair, feed, hygiene, wear clothes and shoes) and during playing sports of the patients.

In the present study, there was low rate of complications only one patient had a pin tract infection that resolved on oral antibiotics and three patients occasionally reported a minimal degree of dull pain that just appears when lifting heavy objects regarding to the other side which didn't affect the function. All patients showed stable elbow joint and there was no ulnar nerve affection found among the current sample. It was reported that peripheral nerve injury occurs among 10-15% of cases having a supracondylar fracture. Moreover, anterior interosseous nerve is the most affected nerve in extension types; however, the ulnar, radial and median nerve injuries can occur. Ulnar nerve injuries are most common among patients with flexion type of supracondylar fractures [13].

Limitation of the study: Small sample size, where only 21 children were included.

### Conclusions

The carrying angle changes following supracondylar humeral fractures managed by closed reduction and K-wires fixation are resulting in satisfactory outcomes represented in good functional outcomes.

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**Conflict of Interest:** Nil

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