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Research Article

Outcomes of Open Reduction and Internal Fixation for Supracondylar Humeral Fractures in Children

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Abstract

Objectives: The aim of this study was to evaluate the results of open reduction and internal fixation of humeral supracondylar fractures in pediatric patients.

Patients and methods: A retrospective descriptive study conducted from 2006 to 2016, including 24 patients who underwent open reduction and internal fixation for the treatment of condylar fractures, adjusted by the closed method. The patients were clinically and radiographically evaluated according to the Gartland's classification. Data collection also included postoperative radiological assessment, range of motion, presence of postoperative complications, and satisfaction questionnaire with treatment received.

Results: Patient's age: Mean 9.46 ± 2.07; Males : 15 (62.5%), Females: 9 (37.5%); Injured elbow: Left 17 (70.8%), Right 07 (29,2%); Injury/Surgery Interval (days): 2.2 ± 0.78; Gartland's classification: Type II: 6 (25%), Type III: 17 (70.8%), Type IV: 1 (4.2%); Follow-up Period (months): 44. 08 ± 5.78; Baumann angle: 16.12° ± 2.23°; Final loss of flexion: averaged 5.9°; loss of extension: 0.73°. The KW was removed was 4.2 months (range: 3 - months). Complications: KW Pierce through brachial artery (intra - Operatively) 1 (4.2%), Iatrogenic ulnar injury 1 (4.2%), Cubitus varus 1 (4.2%). Evaluation: Satisfactory 22 (91.7%), Unsatisfactory 02 (8.3%).

Conclusions: Conservative treatment is recommended for Gartland type I and nondisplaced type II fractures. Open reduction with two or three pins is the preferred treatment option for most supracondylar fractures. The use of appropriate criteria is wise in managing these cracks; Prognosis in the event of complications or possible complications should be explained.

***Keywords:** Supracondylar fracture, Open and internal fixation, Surgical methods, Preservation method of triceps, Kirschner wire.*

Introduction

Supracondylar fractures of the distal humerus are the most common upper extremity fractures in children, accounting for 75% of all humeral fractures in children. Most occur on the left side, in children aged 5 to 7 years, and predominate in males [1].

The fracture line can affect the entire distal humerus and extend toward both columns, lateral, and medial. It is determined by the position of the forearm relative to the arm at the time of the fall. In more than 95% of cases, fractures occur due to an "overextension" mechanism, with the fall and landing in a flexed back and elbow extension. Fractures due to the mechanism of "excessive flexion", with falls and elbow flexion are less common, accounting for less than 5% of all fractures [2]. The goal of the treatment of supracondylar humeral fractures (SCHF) in children is to reduce the fracture anatomically to prevent the occurrence of long-term angular deformities.

In general, conservative treatment is the first choice for type I, nondisplaced type II fractures, and surgical treatment is applied for the remaining types [3, 4]. Surgery is the treatment of choice in SCHF. Arm fractures are an important part of childhood fractures due to their high morbidity, high morbidity, and serious complications [5]. Compression combined with percutaneous fixation has become the treatment of choice for pediatric supracondylar fractures due to better outcomes. However, in most published studies, groups undergoing open reduction often receive this treatment because of previous failure to reduce closed methods. In other words, patients undergoing open manipulation are often those with complex fractures [6].

Several different surgical approaches have been described in SCHF requiring surgical treatment. In the literature, each approach has its positive side and there are a number of publications reporting good results [6].

The aim of our study was to evaluate the outcome of surgical treatment with open reduction and internal fixation of SCHF in children.

Material and Methods

This is an observational, descriptive and retrospective study performed at the Pediatric Orthopedic Department, National Hospital of Pediatrics, Hanoi Vietnam.

Informed consent was obtained from all participants. The study had the approval of the Ethical Review Committee of our Institute and was carried out in accordance with the tenets of the Declaration of Helsinki.

In patients under 15 years of age who underwent internal, open and fixed orthopedic surgery between 2006 and 2016, due to SCHF. A total of 24 open surgical procedures were performed on 24 patients during this period. We included patients who had undergone open surgery and internal fixation due to failure of conservative treatment.

However, the final number of patients who were located and met the inclusion criteria was 24. We collected demographic data including sex, age, anthropometric characteristics, and mechanism, and trauma causes, related trauma, as well as information on surgical and postoperative interventions, through the application of protocol questionnaires. In the nterview on the topic of this study, we performed radiographic examination and also collected clinical data and information on joint surgical exploration. These include range of motion using a multimeter, residual chronic instability using joint tension maneuvers (lateral examination to diagnose posterior instability, and check the valgus stress for instability). intermediate definition.

Clinical examination

Although elbow deformity is often the most prominent aspect (especially in very displaced fractures), examination of the entire extremity is essential to rule out the associated distal radius (most common), fracture forearm or head near the humerus. Concurrent upper extremity fractures not only cause more severe trauma and instability, but also increase treatment difficulty and increase the incidence of neurovascular injury or compartment syndrome.

In displaced extension fractures, the so-called 'S-deformity' is often present. however, mild bruising or swelling may be the only outward manifestation of slight displacement or fracture of the flexor muscle. Signs such as extensive bruising, swelling of soft tissues, and wrinkling of skin indicate serious injury. Particular attention should be paid to the appearance of wrinkles on the skin. This sign occurs when the proximal segment passes through the brachial muscle, 'folding' the deep dermis. For this reason, when skin wrinkling occurs, severe displacement and damage to soft tissues, including the brachial artery, and medial nerve compression [7] can occur, although without No difference was found in terms of long-term results with proper management.

Evaluation of vascular status is paramount in displaced fractures. It has been reported that vascular damage exists in about 10% to 20% of displacement fractures. Pulse and perfusion of the hand before and after surgery is mandatory.

The neurological examination can be challenging. In acute cases, the pain and anxiety of the child and the child's parents can make examination difficult. however, sufficient time is needed to fully assess the preoperative neurological status. The median and anterior interosseous nerve can be evaluated by active flexion of the interphalangeal joints of the thumb and index finger. For the radial nerve, thumb extension is usually easy to achieve, even in young children. To evaluate the ulnar nerve, it is usually easy to obtain at least the first interosseous constriction. The inability to perform a complete neurovascular assessment must be documented for legal reasons.

Compartment syndrome should always be kept in mind, especially when skin wrinkling, severe bruising/swelling, vascular changes, or concurrent forearm fractures occur.

Radiological evaluation

Standard anteroposterior (AP) radiographs and actual lateral radiographs of the elbow are usually sufficient to characterize the fracture. Careful evaluation should be performed, because the severity of the fracture is often underestimated due to inadequate radiographic techniques. A realistic view of the elbow is essential because most classifications and treatment algorithms are based on the degree of extension or flexion displacement.

The main anatomical landmark assessed on the lateral side is the anterior humeral line (AhL). This line joins the anterior cortical portion of the humerus and, at a normal elbow, cuts through the crest in its medial third (Fig. 1). In a displaced fracture in extension, AhL will cross anteriorly or may not even cross the capitellum. In the case of a flexural fracture, the AhL moves posteriorly to the apex. The side view also allows assessment of the degree of displacement and the integrity of the posterior cortex.

Anterior and posterior 'fat pad signs' can also be assessed on lateral radiographs. Although the diagnosis of a displaced fracture is often obvious, diagnosing a fracture with little or no displacement can be challenging. Posterior fat pad sign suggests the presence of a nondisplaced elbow fracture. According to Skags et al. [8] 76% of patients with a positive fat pad sign had nondisplaced elbow fractures and 53% of them had supracondylar fractures. however, anterior fat pad may be present in normally flexed elbows and is therefore not very specific for the diagnosis of fracture.

Anterior humeral line (AhL)

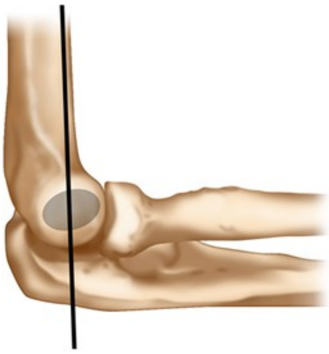


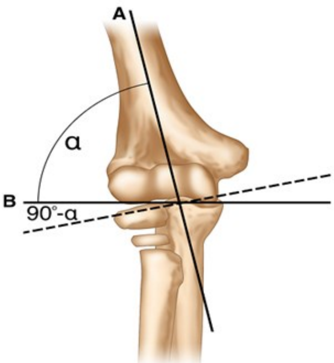
Figure 1: *The anterior humeral line should cross the capitellum on a true lateral view of an uninjured elbow.*

The humeroulnar Angle

Figure 2: *Humeroulnar Angle defined as the angle formed between (**A**) the longitudinal axis of the humerus. and (**B**) the axis of the proximal third ulna (normal range 5°–15°) [9].*

The ulnohumeral angle (HUA) or bearing angle on radiographs, which is the angle formed, in AP view, the diaphragmatic axis of the humerus and the axis of the proximal third of the ulna (Fig. 2), is also obtained. used to assess scoliosis deformities or curvature and it is more accurate and useful than the Baumann's angle (normal 5°–15°).

Baumann's angle



Baumann's angle (also known as Humerocapitellar angle) serves as a necessary indicator of alignment and development of the elbow joint. It is an important help for Precise reduction of supracondylar brachial fractures young. It also provides valuable insights into development of the distal humerus and can help identify different and unusual condition

Figure 3: *Baumann's angle is a radiographic angle created by the intersection of a line drawn down the humeral axis (**A**) and a line drawn along the physis, (**B**) of the lateral condyle of the elbow on the AP view of the elbow (normal range, 9°–26°).*

We calculated the "Baumann's angle" (BA) from the postoperative radiographs (Fig. 3). This angle is formed by the perpendicular of the longitudinal axis of the humerus to the axis of the physical line (normal range: 9–26°) [10]. For AP radiographs, we should assess the direction of displacement, the presence of an internal or medial crooked alignment, and the extent of the fracture. However, the Baumann's angle has many normal values and varies greatly with radiographic humeral position (that is, rotation).

Classification

All fractures were graded according to the Gartland scale [11] through preoperative radiological evaluation. To evaluate fracture reduction. Several classifications of supracondylar fractures of the humerus have been proposed. However, Gartland's classification is the most widely used. This is a reliable classifier with a high observer-to-observer fit based on the degree of displacement of the distal segment. Gartland classified an extension crack on the condyle in his original paper as follows (Figures 4):

- Class I. Non-displaced fracture (<2 mm). AhL still passes through the center of the capitellum. These cracks are stable because of the integrity of the pericardium.

- Type II. Moderate displacement (>2 mm). AhL stands at the center of the capitellum; The posterior periosteum is intact but acts as a hinge.

- Type III. Completely relocated. This type of fracture is more unstable, with widespread soft-tissue and periosteal damage and an increased incidence of neurovascular injury.

***Figures 4: A–C**. Lateral radiographs are shown for Gartland (**A**) type I, (**B**) type II, and (**C**) type III supracondylar humerus fractures.*

Wilkins [12] modified Gartland's classification to make it more clinically relevant, including the concept of posterior humeral cortical contact. Nondisplaced type I extension injury; Type II injuries anteriorly displaced (anterior humeral crest versus crest (Figure 1) but with posterior humeral cortical contact; and displaced type III fractures without cortical contact. class II into categories IIA and IIB: Class IIA fracture without rotational or fragment abnormalities Leitch. 2006 [13] added Type IV (it was not described in the original Gartland's classification and diagnosed intraoperatively technique): displacement, with periosteal disruption, instability in flexion and extension.

Surgical technique

Reduction

Open reduction is indicated when the surgeon is unable to correct the fracture with a closed approach, when soft tissue is involved (i.e. muscle, median nerve, brachial artery), or when the hand cold still not perfused after trying to close manipulation. was made. A neural trap may be suspected when a soft stop for reduction is observed.

Fractures can be reduced by closed or open means. [14]. Reduced openness is associated with higher rates of infection and stiffness. Sealing is a reliable technique for the majority of displaced fractures.

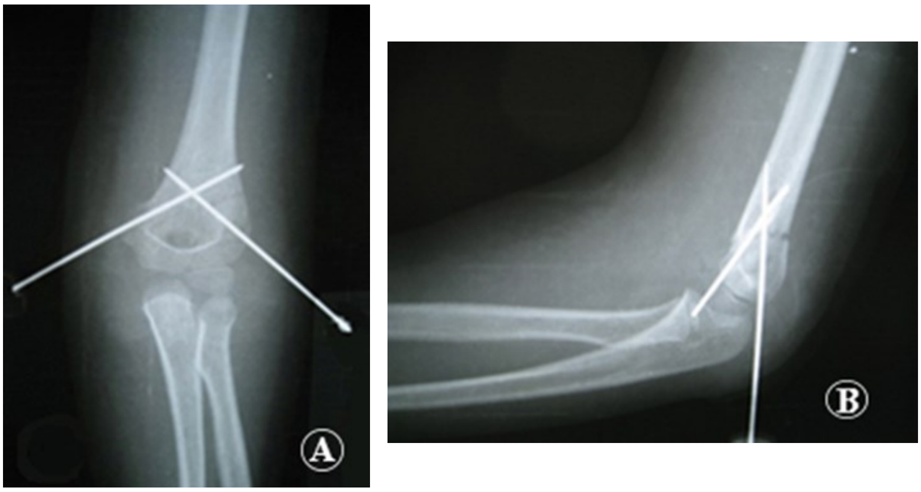
The posterior approach is an easy and safe approach that allows the surgeon to manage both columns for proper collapse. Classically, the open approach is associated with a high rate of complications, such as stiffness or musculoskeletal inflammation. However, recent studies have reported a lower rate of complications and no difference compared with closed manipulation with regards to loss of mobility, infection, malformation, or subsequent surgery. In a series of reports by Reitman et al. [15], the authors found that open reduction surgery had a low complication rate.

In our opinion, vascular entrapment and type II or III open fracture are the main indications for open manipulation. We attempt to close by means of all fractures without vascular involvement, all possible procedures to avoid open manipulation. When fractures require opening due to vascular injury, we use the open reduction.

All patients were opened and fixed internally with a Kirschner wire. We used a Medio-posterior approach with neurolysis of the ulnar nerve and partially separated and tenotomy of the triceps in a “V” shape is included, exposing the posterior aspect of the humerus for compaction and fracture synthesis. To avoid prominence of bone composites at the onset of elbow mobility. The KW tip is bent and brought close to the shell of the humerus outside the superior condyle. Triceps tendon recovery stitch, the skin covered. Once the fracture is immobilized, the surgeon can extend the elbow and check for stability.

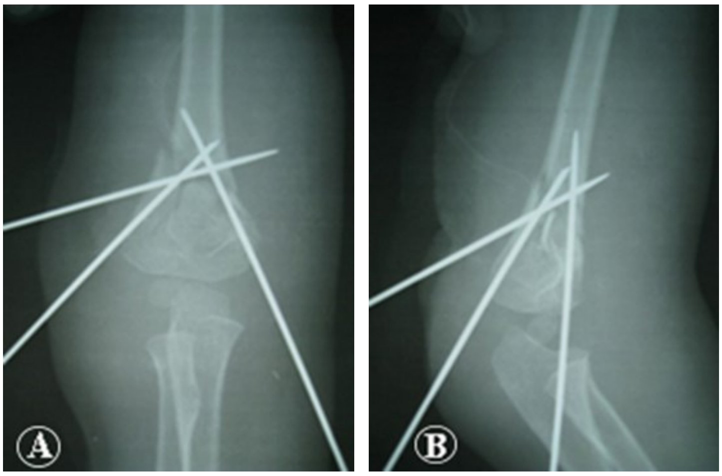
Fixed with Kirschner wire

Before fixing, angle alignment and rotation are evaluated. We also observed that, clinically, the position of the forearm relative to the trunk with the shoulder abducted and the great external rotation was symmetrical and played a role in controlling the rotation of the distal fragment. We used two different K-wires inserted from the inside and the inside above the condyle (Figures 5), or an additional third K-wire if the crack appeared unstable (Figures 6). We typically use a pin diameter that includes a 0.062 inch (1.6 mm) K-wire in patients ≤20 kg and a Steinmann pin 5/64 inch (2.0 mm) in patients > 20 kg. The two ends of the KW enter the condylar process, are bent, and placed under the skin. In all cases, the surgical limb was immobilized with a brace or brachial plexus cast for 4–6 weeks. The bone mixture was removed after the eighth or ninth week.



Figures 5: A-B*: Postoperatively, pining two Kirschner wire,* ***A****. A-P Radiography;* ***B.*** *Lateral Radiography.*

If the fracture remains unstable, a third-party entry point or a plug from the middle of the elbow will be inserted. We prefer to use a third-party entry point K cord instead of a central pin because of the risk of damage to the ulnar nerve (Figure 6).



Figures 6: A-B. *Postoperatively, pining three Kirschner wire,* ***A****. A-P Radiography;* ***B****. Lateral Radiography.*

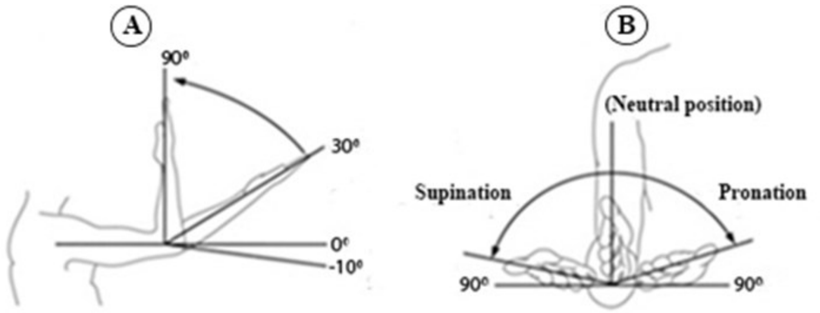
The criteria developed by Flynn (Table 1) [12].

All patients were evaluated according to the Flynn criteria [16], assessing both functional and aesthetic outcomes. The aesthetic component considers the load angle and its deflection to curvature or valgus, while the functional component is evaluated by measuring flex and elongation. The lower of the 2 outcomes (esthetic and functional) is considered the overall outcome. “Excellent”, “Good” , “Fair”, “Poor”, and “Average” results are considered satisfactory (these results reflect load loss and mobility angles between 0–5°, 6–10° and 11–5). 15°, respectively), while a “poor” result (loss >16°) was considered unsatisfactory (Figures 7). An outcome with cubitus varus is implicitly considered a “poor” result (Table 1).

We also collected a subjective index of patient satisfaction (very satisfied, satisfied, neither satisfied nor disappointed, slightly disappointed, very disappointed) and the presence of practical difficulties. performing activities of daily living related to fracture (Table 2).

Table 1: Modified Flynn’s Criteria [16].

Outcome	Rating	Cosmetic factor (carrying angle loss in degree)	Functional factor (movements Loss In degree)
Satisfactory	Excellent	0 - 5	0 - 5
	Good	6 - 10	6 - 10
	Fair	11 - 15	11 - 15
Unsatisfactory	Poor	< 15	> 15



***Figures** 7: **A-B. A**. The measurement of elbow flexin-extension.*
***B**. The measurement of elbow supination-pronation. [17].*

Table 2: Range of motion of the elbow and wrist [17]

Joint action	Position for examination	Normal range of motion
Elbow		
Extension	Shoulder at 90 degrees abduction	0 degrees
	Palm facing up	
Flexion	Shoulder at 90 degrees abduction	150 degrees
	Wrist supinated	
Supination	Elbow flexed at 90 degrees touching the iliac crest Hand in neutral, perpendicular to ground.	90 degrees
Pronation	Elbow flexed at 90 degrees touching the iliac crest	90 degree
	Hand in neutral, perpendicular to ground	
Wrist		
Flexion	Elbow at 0 degrees	90 degrees
	Hand fully pronated	
Extension	Elbow at 0 degrees	70 degrees
	Hand fully pronated	

Statistical analysis

Statistical analysis was performed using the SPSS statistical package program (SPSS version 19.0; SPSS Inc., Chicago, Illinois, USA). The t-test was performed to compare injured and uninjured elbows. The null hypothesis was that the mean extension and angle of inclination in the injured elbow after fixation would be the same as in the uninjured elbow (control). We used a P value of less than 0.05 to determine the statistical significance of the respective variables.

Result

Of the 24 patients included in the study, 15 males (62.5%) and 9 females (37.5%), with a mean age of 9.46 ± 2.07 years (range: 5-15 years). Injury to the right elbow in 14 cases (58%) and the remaining 10 cases on the left side (42%). The mean follow-up time at the time of assessment was 44.08 ± 5.78 months (range: 38-56 months). Regarding the mechanism of injury, it is difficult to assess the degree of fracture because the patient was young at the time of injury. Most occur from falls from one's own height, slips, or falls from a bicycle.

According to the Gartland's classification, 25% (n = 6) of cases corresponded to Type II, Type III 70.8% (n = 17) and Type IV 4.2% (n = 1) of this total.

The mean Baumann angle, as measured by radiographs immediately after surgery, was 16.12° ± 2.23 (range: 12-21°). The mean time elapsed until satisfactory range of elbow motion was restored was 5.625 ± 0.57 months (range: 4 - 7 months). The mean time elapsed until osteosynthesis was removed was 4.2 months (range: 3-8 months) (Table 3).

Table 3: Data of the Patient.

Cases	Age (Years)	Injury/ Surgery Interval (days)	Time for union (weeks)	Surgery/full ROM Interval (weeks)	Follow-Up (months)	Baumann angle (°)	Complications
1	10.8	3	11	6	38	12	No
2	6.5	2	5	4	39	21	No
3	10.0	2	10	6	42	18	No
4	7.3	3	7	6	54	15	Iatrogenic Ulnar injury
5	8.1	2	7	5	38	14	No
6	12.7	5	11	6	44	17	No
7	11.8	3	10	5	39	18	No
8 Three pins	14.6	2	12	4	38	14	No
9	5.8	4	6	4	42	16	Cubitus varus
10	7.6	2	7	6	44	14	No
11	8.3	3	8	7	56	17	* Pierce through Brachial Artery
12	11.2	2	10	6	46	19	No
13	6.8	2	6	4	42	15	No
14	7.3	2	7	5	54	18	No
15	11.2	2	12	6	46	14	No
16	8.1	3	12	5	42	18	No
17	6.7	2	7	4	44	16	No
18	7.4	2	7	6	38	19	No
19	12.9	2	11	6	38	16	No
20	11.4	2	10	5	54	14	No
21	8.5	3	8	6	42	16	No
22	13.4	3	11	6	44	13	No
23	11.8	2	10	5	52	14	No
24	6.9	2	7	4	42	18	No
Mean ± SD	9.4625 ± 2.07	2.2 ± 0.78	8.8333 ± 2.20	5.625 ± 0.57	44. 083 ± 5.78	16.125 ± 2.23	

* KW Pierce through Brachial Artery intra Operatively

Age: Mean 9.4625 ± 2.07; Sex: Males : 15 (62.5%), Femeals 9 (37.5%); Type fracture: Extension 21 (87.5%); Flexion 3 (12.5%); Injured elbow: Left 17 (70.8%), Right 07 (29,2%); Injury/Sugery Interval (days): 2.2 ± 0.78; Gartland Classification, Type II: 6 (25%), Type III: 17 (70.8%), Type IV: 1 (4.2%); Two pin (crossed pin): 23 (95.8%), Third pin: 1 (4.2%); Time for union (weeks): 8.833± 2.20; Foll-up Period (months): 44. 08333 ± 5.78; loss of extension: 0.73° (range: 0-11°) (Table 2); Baumann angle (°): 16.125° ± 2.23°; Final loss of flexion: averaged 5.9° (range: 0-19°) (Table 3); and Complications: Iatrogemic Ulnar injury 1 (4.2%) (patient 4), Cubitus varus 1 (4.2%)(patient 9), Pierce through Brachial Artery 1 (4.2%) (patient 11) ; Number and size of Kirschner wire used: 4 patients KW 2 mm, 9 patiens KW 1.8 mm, 11 patiens KW 1.7 mm. Iatrogenic ulnar injury 1 (4.2%); Cubitus varus 1 (4.2%) (Table 4)

Evaluation: Excellent 17 (70.8%) , Good 03 (12.%%), Fair 02 (8.3%), Poor 02 (8.3%), Satisfactory 22 (91.7%), Unsatisfactory 02 (8.3%)

- Pierce through Brachial Artery intra-Operatively.
- Iatrogenic Ulnar injury (Postoperative 10 weeks).
- Cubitus varus (Postoperative 42 months).

Table 4: Complications in this study.

Postoperative complication	Number of patients
Pierce through Brachial Artery	1 (4.2%)
Iatrogenic Ulnar injury	1 (4.2%)
Cubitus varus	1 (4.2%)

One patient (4.2%) Perforated brachial artery intra-operation; The patient was examined elbow and wrist with perfectly good function, Postoperative 54 months. There was one case of cubitus varus (4.2%) and one patient with iatrogenic ulnar injury (4.2%) (Table 4). There were no cases of deep infection, Volkmann ischemic muscle spasticity, pseudo arthritis or ossification myositis.

According to Flynn's criteria, we obtained positive results in 91.7% of patients (n=22) (Table 5). Therefore, when analyzed independently for aesthetic factors (loss of load angle), 83.3% (n=20) of patients had results within what is considered normal (Table 5). On independent analysis of functional factors, 20 patients (83.3%) had elbow range of motion with values within the limits considered normal (flexion: 140-160°; extension: (−10) - 0°; prone: 80 -90°; back: 80-90°) [19].

Table 5: Outcome in this study according to Modified Flynn's Criteria [18].

Outcome	Rating	Number of Patient	Percentage (%)
Satisfactory	Excellent	17	70.8
	Good	03	12.6
	Fair	02	8.3
Unsatisfactory	Poor	02	8.3

The mean deficit at the end of the follow-up period was 5.1° for flexion (range: 0-20°), 0.71° for extension (range: 0-10°), 0.83° for prone position (range: 0-35°) and 2.85° for supine position (range: 0-20°). Patients undergoing re-intervention had the longest range of motion relative to normal values, particularly for flexion and pronation (−20 and −35°, respectively). According to the load angle or swing arm angle measurement on the radiograph obtained at the end of the follow -up period.

Discussion

Compared three methods

Ababneh M et al. 1998 [20] have compared three methods for operative supracondylar humerus fracture (Table 6&7). The main objectives of treatment of displaced SCFs in children are the prevention of Volkmann's contracture, the avoidance of deformities, and of normal function.

Table 6: Ababneh 1998. reported results of each method of treatment using the criteria of Flynn et al.

Method of treatment	Results			
	Excellent	Good	Fair	Poor
Closed reduction and application of cast (n = 45)	36%	24%	9%	31%
Closed reduction and percutaneous wire fixation (n = 37)	76%	11%	5%	8%
Open reduction and wire fixation (n = 53)	55%	19%	4%	22%

Table 7: Ababneh 1998 analysis of poor results of 3 methods.

Method of treatment	Loss of Motion	Cubitus varus	Cubitus valgus	Total
Closed reduction and application of cast	5	9	-	14
Closed reduction and percutaneous pinning	-	2	1	3
Open reduction and wire fixation	5	7	-	12

The injury rates involved in this study were comparable to those reported by others. The time required to return to the zero radial pulse after reduction and steady positioning of the elbow is also comparable. Probing of the brachial artery is justified in cases where signs of ischemia persist after ablation because dysfunction can occur after a negligible degree of ischemia, as in anterior branch compartment syndrome [21].

The best results achieved by hermetically shrinking and immobilizing the cord are judged by the highest excellent results and lowest poor results rates; Similar observations have been made by others. Three patients had poor outcomes with internal and external deformities due to unsatisfactory initial reduction. The rotation of the distal fragment leads to such deformations [21].

Others have reported high rates of poor outcomes with casts and closed casts. The relatively large number of poor outcomes after dilatation and wire fixation is attributed to the high rate of severe displacement grade III fractures (74%) in this group and to the delay in initiating therapy. treatment due to late arrival to the hospital. hospital up to 10 days. Open surgery through short mid- and lateral incisions has the best results.

The best treatment is early retraction and percutaneous fixation of the arch wire. Open manipulation and wire fixation should only be reserved for cases with signs of Volkmann's ischemia, primary vascular or nerve rupture, open fracture, and fracture with severe swelling that does not permit manipulation. adjusted to an acceptable level. Cast and closed casts are associated with a high risk of vascular impairment, may produce unacceptable results, and should only be considered in grade I fractures.

Some approach for Open reduction of supracondylar humerus fracture

Open reduction is indicated when the surgeon is unable to correct the fracture with a closed approach, when soft tissue is involved (i.e. muscle, median nerve, brachial artery), or when the hand cold still not perfused after trying to close manipulation. was made. A neural trap may be suspected when a soft stop for reduction is observed.

The former method is the most widely used method to reduce openness. This approach is especially indicated when vascular repair is needed. It is a safe approach and results are similar or better than the traditional lateral approach [22]. The lateral approach is the standard method for elbow surgery. however, in extracondylar, supracondylar fractures, it does not confer any advantage over the anterior approach and increases the risk of radial nerve damage and stiffness. The posterior bilateral apical-to-vertebral approach (the Alonso-Llames method) was originally described at our facility for the treatment of supracondylar fractures [23], however, this approach is currently available. are not widely used due to the high rate of complications described, such as stiffness, poor scarring, and the risk of complications. trochlea osteonecrosis. In our experience, the posterior approach is an easy and safe method, allowing the surgeon to manage both columns for proper collapse. Classically, the open approach is associated with a high rate of complications, such as stiffness or musculoskeletal inflammation. however, recent studies have reported a lower complication rate [15] and no difference compared with closed manipulation regarding loss of motion, infection, malformation, or subsequent surgery. . In a series of reports by Reitman et al. [15], the authors found that open reduction surgery had a low complication rate. however, despite the fact that fractures requiring open manipulation were often more severe, up to 22% of their patients were assessed as having poor or good outcome according to Flynn's criteria after a mean follow-up of 5 years. ,8 months. Loss of movement is the most commonly reported complication, affecting about 10% of patients. In our opinion, vascular entrapment and type II or III open fracture are the main indications for open manipulation. We attempt to close by means of all fractures without vascular involvement, all possible procedures to avoid open manipulation. When fractures require opening due to vascular injury, we use an anterior approach.

Kirschnet wires for Supracondylar humeral fracture

Effect of Number of Pins on Fracture Stability

Proper pinning technique and understanding of the fracture pattern are essential to avoid failure. Sankar et al. [24] reported 7 cases of unsuccessful fixation using lateral staples; 4 because there is only 1 pin in the distal part, 2 split pins are not enough in the broken position and 1 does not have 2 sides of the shell. They did not report whether there was anatomical relief compared with mild fractures. Bloom et al [25] performed a biomechanical study of fracture pinning in mild fractures. He concluded that anatomically reduced fractures could be treated with 2 pins; however, an additional third pin is cautious for internal slightly rotated cracks to improve stability and prevent further loss of downforce.

Current research supports this conclusion; we observed no difference in structural stiffness for the number of pins placed. We were able to achieve anatomical reduction in each of the minor sawbone models by pre-drilling the pin grooves prior to osteotomy Certain fracture types are inherently more unstable than others. Larson et al [26] performed a biomechanical study showing a decrease in torsional stability in the presence of mid-column crushing. In this type of fracture, additional fixation may be warranted; middle latch or third party latch.

Effect of Pin Size on Fracture Stability

There is also limited information on pin size related to the stability of supracondylar brachial fractures. Many previous biomechanical studies used 1.6 mm pins for fixation [26] ; compared to clinical studies that used 2.0 mm feet for stabilization. Most recently, Srikumaran et al [27] performed a retrospective study to analyze the effect of pin size in stabilizing cracks in the sagittal plane. They defined the pin size group based on the ratio of pin diameter to cortical thickness; small if the ratio is 0.9 and large if the ratio is > 0.9. Pin sizes range from 0.9 to 3.6mm (most commonly used pins are 1.6 and 2.8mm). They concluded from their study that the large pin size group was significantly better able to maintain vertical alignment at the last follow-up than the small pin size group [28]. The present study demonstrated that the 2.0 mm socket structure is stiffer than the 1.6 mm pin configuration in terms of orientation, internal rotation and external rotation, $P<0.05$, but no difference in aperture wide. In addition, we have shown that two 2.0 mm pegs placed through the horizontal start point directly are equivalent to three 1.6 mm pegs (the start of the flower head) and are better than three 1.6 pegs. mm (direct side view) in terms of internal and external rotation. The trend was similar in the capitellar starting group.

It makes sense that larger pins would provide more stability, but not all patients need larger pins. Kocher et al [28] used body weight to determine whether a 1.6 mm pin should be used versus a 2.0 mm pin. If the patient weighs ≤ 20kg, use a 1.6 mm nail; and if the patient weighs >20kg, choose the 2.0mm pin. Srikumaran et al [25] determined the pin size as the ratio of the pin diameter to the patient's midbrachial cortical thickness; for "large" latch, the ratio must be >1.

Starting capitellum of Kirschner wire.

Larson et al. [26] showed that the three different side pins are at least as stable as the standard cross pins. Skaggs et al [29] found that lateral entry alone was effective for even the most unstable fractures. The authors note the importance of maximally separating the pins at the fracture site, inserting the medial and lateral columns near the fracture, setting enough bone in both the proximal and distal segments, and maintaining a low threshold. to use a side third pin if there is any concern about crack stability or the location of the first two pins. Biomechanical studies have demonstrated that widely diverging cords starting in the cerebral cortex, one through the lateral column and the other through the midbrain, are the best choice. It is important to separate the pins sufficiently at the fracture level to provide rotational stability.

Several studies have demonstrated a higher risk of ulnar nerve injury with cross pin placement rather than lateral entry alone, with no difference in other parameters. The relative risk (RR) of the ulnar nerve was 4.3 times higher for cross-stapled versus lateral staples with an estimated ratio of 3.4% versus 0.7%.

It is important to know that direct trauma (such as puncture) of the nerve from a pin is not necessary for the development of ulnar nerve palsy. The fact that the K nerve is adjacent to the nerve has been shown to cause ulnar nerve conditions. The main advantage of using cross pins is to provide greater stability to prevent secondary displacement and misalignment.

Several techniques have been proposed to avoid injury to the ulnar nerve by inward stapling. After the lateral pins have been inserted, the elbow will be half extended to allow the ulnar nerve to move posteriorly. With elbow flexion >90°, the ulnar nerve is displaced anteriorly and the risk of injury ranges from 5.7% to 17.7%. The thumb is used to press on the epithelium to reduce edema and facilitate palpation of the reference bones. The thumb is then moved back to protect the nerve and a T-handle is used to insert the pin into the front of the thumb. A small midline incision can also be used to visualize the medial entry point and avoid damage to the ulnar nerve. Locating the ulnar nerve by palpation is not a completely safe technique. Other techniques such as intraoperative electrical stimulation or ultrasound monitoring have been proposed as safe but highly technical methods to avoid damage to the ulnar nerve.

Classification systems.

As in any major fracture, the treating physician's effort is to be able to classify the fracture with the help of a simple, reliable, reproducible, and determinate classification system. treatment items. Although supracondylar fractures have been studied by many authors, the search for a classification that meets all criteria for widespread clinical and research use is ongoing. The Gartland classification with its Modified version is the primary classification used in English-speaking countries while the Lagrange and Rigault classification [30] is widely used in France and most French-speaking countries. The shortcomings in both of these classifications have led clinicians to develop different modifications as well as new classifications. To date, as many as six to seven major classification systems exist that are used in various parts of the world, all with their own set of positives and negatives.

Gartland/ Wilkins Modified Gartland's classification.

Gartland [11] described his classification of extended supracondylar fractures in 1959 according to the degree of displacement into three categories - nondisplaced, minimally displaced, and displaced. However, this classification was described as too simplistic and was therefore revised in 1984 by Wilkins [12] with more details and explanations. In this classification, a type I fracture is either undisplaced or minimally displaced such that the anterior humeral line passes through the ossification center of the crest. Type II fractures have a clear fracture line with displacement of the distal fragment. The anterior humeral line passes through the front of the crest. The frontal cortex is disrupted but the posterior cortex remains intact. The direction of displacement may be directly rearward or angled in the middle or to the side and may have a rotating element. Class III fractures are significantly displaced fractures without cortical contact with posterior intra or posterior displacement. For ease of understanding, Wilkins also classifies type II and III fractures into A (without rotation) and B (with rotation).

A general protocol for management has been developed by Gartland for Type I fractures immobilized with a cast long arm in the 75-80° flexion range. Stable type II and type III fractures are treated with reduced manipulation under anesthesia and a long arm cast while unstable type III fractures are treated with traction of the bone through the bore with the elbow extended (K-wire fixation was not the norm or care at that time). Since the concept of "stability" as described by Gartland is so vague, Wilkins described the rotational component of the decision-making process. He said that type II non rotator cuff fractures (type IIA) only require correction and cast of the long arm, while rotator cuff fractures (type IIB) require closure and immobilization of the k-wire and therefore need to be treated. as type II trauma.

A modification of the Wilkins classification was described by Leitch et al in 2006 in which multidirectional unstable fractures were described as type IV [13]. Type IV (not described in the original Gartland classification and diagnosed intraoperatively): displacement, with periosteal disruption, instability on flexion and extension, diagnosed intraoperatively only. This type of fracture is unstable in both flexion and extension and is a high-energy injury that results in a circumferential loss of the periosteal hinge that maintains a reduction in type II and III injuries. The treatment of these type IV injuries is difficult and many authors have proposed their own modifications to the K-wiring technique for the same case. Wilkins' modification of the Gartland classification, although very simple and elegant, is not widely accepted due to its reliability and reproducibility issues, especially in type II and type IIIA. There have been many studies describing inter-observer and intra-observer variability of the modified Gartland classification. We had a patient with a Class IV (Patient 8, Table 3) in this study.

Heal et al [31] in their paper found associated host reliability poor in type I and only moderate to moderate reliability for type II injury. As expected, type III and type flexion injuries ranged from good to very good among observers. Another study by Silva et al [32] found moderate to good observer-observer reliability even though they said that 10% of the time, a second reading by the same person was different. and they concluded that "this makes treatment recommendations based solely on the incorrect fracture types." These studies have led to the search for newer and better classifications that do not have the disadvantages of the modified Gartland's taxonomy while preserving its simplicity.

Lagrange and Rigault classification.

Lagrange and Rigault [33] described this classification in 1962 and since then it has become the most widely used classification system in France and other French-speaking countries. Extended humerus supracondylar fractures are divided into 5 types - Type I - nondisplaced fractures involving mainly the anterior cortex of the humerus. Type II is a fracture involving the cortex but with little or no displacement. Type III fractures are displacement fractures but in which there is some contact between the proximal and distal fragments. Severe displacement type IV fracture with no contact between proximal and distal fragments. The last type, a type V fracture, is essentially a metaphysical fracture (supercapsular fracture) that is quite unstable.

Since the Lagrange and Rigault systems are used in only a few countries, little is known about their reliability and reproducibility. De Gheldere et al. in 2010 [34], discussed the repeatability of the classifier and found good intra-observer and observer reliability, albeit within a similar range of the Gartland classifier. . So, what is the necessity of these two classifications and what is the difference between the two? Most clinicians feel that Gartland Type I resembles Legrange I and Gartland Type III resembles Legrange Type IV. Types II and III in Legrange's classification are similar to Gartland's type II in some cases and types I and III in some cases and this has in fact added to confusion in classification and treatment treat these wounds.

AO displacement based validated classification.

Looking at the shortcomings of the two main classification systems, the AO team has come up with a continuum with the AO classification of childhood long fractures under development. They planned to design a system that was simple but clinically relevant, standardized, validated, and reproducible. Lutz et al. [35] together with a team of six experienced pediatric orthopedic surgeons at five different centers validated this approach and presented their findings in their paper in 2011. According to Lutz et al., they achieved good to very good diagnostic accuracy and reliability with this classification. The feature of this classification is that some importance is given to the AP view as well as compared with the Gartland classification, where much of the stress is on the lateral view. The classification is as follows:

Grade I: Incomplete fracture: Here, the Rogers Line (anterior humeral line) intersects the crest and there is no more than 2 mm of crooked angle on the AP image.

Grade II: Incomplete but angular fracture: This corresponds to a Gartland class II injury but is elaborated in more detail. Here, the Rogers line is before the capitellum. The size of the humerus cap is determined by drawing a circle about the same diameter as the humeral axis and placing the circle on top of the humerus. There is also more than 2mm of varus-valgus angle on AP view.

Grade III: Complete fracture: No bone continuity but some contact between fractures regardless of displacement type.

Grade IV: Complete fracture: There is no bone continuity and there is no contact between the fractures. There is significant bone shortening and overlap of fragments.

This grading system has been extensively evaluated by a panel of experienced pediatric orthopedic surgeons and has been found to have excellent inter-observer and internal reliability. The addition of grade III also seems to have eliminated one of the main concerns of the Wilkins-Gartland classification, which is that some fractures are more displaced than grade II fractures but less displaced than grade III fractures.

The AO classification certainly goes a long way in creating a reliable and relatively easy-to-use standardized system for supracondylar humeral fractures. However, it still has some shortcomings. Perhaps the most important are the multiple rotation fractures, which appear to be less displaced than the usual type IV (according to the AO classification) and as such are classified as type III in the AO classification. These fractures are sometimes even more difficult to relieve than severely displaced Class IV fractures. Therefore, to classify them as lower fractures than type IV might be misleading.

The other issue is that there are certain characteristics of each fracture pattern that are much more important than simple fracture types or grades in determining the prognosis of that particular fracture. Features such as coronal and longitudinal plane angles, crack obliqueness and crack degree are important and as such have been shown to have a definite impact on the subsequent crack healing. This. With such a view, Bahk et al. [35] have provided an excellent classification to elucidate these points.

The "pattern-based" classification.

Bakh et al. in 2008 [36], retrospectively evaluated more than 200 cases with multiple fractures of the humerus and classified them by fracture type. Accordingly, 4 coronal plane models (typical transverse, intermediate oblique, lateral oblique and high fault) and 2 sagittal models (low sagittal and high sagittal) have been described. With the help of these templates, it is very easy for the practicing clinician to understand the severity of the injury, the ability to communicate, the likelihood of complications such as rotator cuff and open dislocation. wide. The internal and external obliques of the fracture also help determine the pin configuration because the central oblique fracture can be pinned inwards while the oblique and transverse fractures are very stable with only lateral pinning. High supracondylar fractures require internal and external cross pinning. The authors also quantified the inclination of the fault plane on the longitudinal and longitudinal sections and suggested that longitudinal plane obliquity greater than 10° and longitudinal plane obliquity greater than 20° were associated with many complications. than. Therefore, any crack beyond 10° coronal and 10° oblique sagittal requires additional stabilization in the form of a third or cross pin. This bug is relatively easy to use, simple, and has been found to have excellent reliability in internal and observer studies.

Complications

Neurological injury.

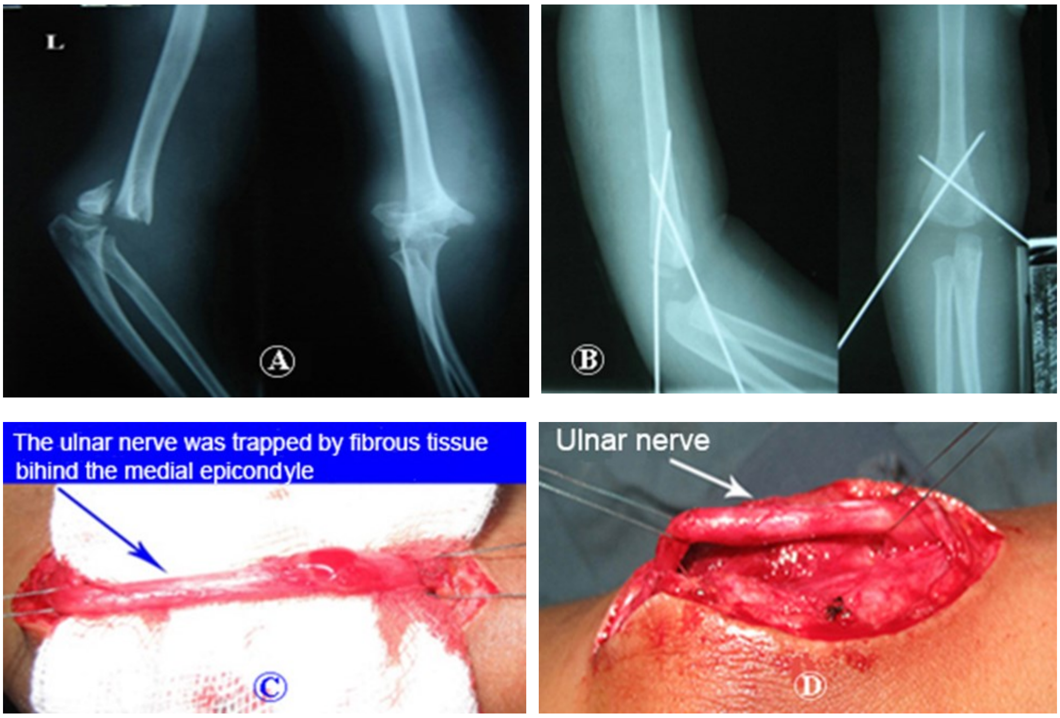
Traumatic neurapraxia is commonly associated with supracondylar fractures, with a reported incidence of 11.3% [37]. The anterior intervertebral nerve (AIN) is most commonly involved, but the incidence varies according to the type of injury. The median nerve, and especially the AIN, is most commonly involved in extension fractures (34.1% of neuropathy involved), while the ulnar nerve is often associated with less common fexion fractures. was more common (91.3% of associated neuropathy) [38] and was likely related to the direction of displacement of the distal humeral fragment. McGraw et al. [38] identified an association between posterior lateral displacement and median nerve injury and posterior medial displacement with an equal incidence of radial, medial, and radial nerve injury.

Treatment-induced nerve damage can occur after closed manipulation, percutaneous fixation, or during open procedures for vascular manipulation and exploration. Babal et al. [35] reported a meta-analysis, which included 5154 fractures, and identified a significant risk of injury to the ulnar nerve by means of the medial and lateral nerves, although the only lateral nerves were at risk. ulnar nerve injury is significantly lower, but this technique is risk-free and is associated with median nerve damage. Prashant et al [39] reported a treatment-induced ulnar nerve palsy rate of 6% with the internal stapling method and none with the lateral stapling method.

Brown et al. [40] reported an evaluation of 162 fractures with 4 cases of direct nerve injury and Blakey et al [41] observed that two ulnar nerves were transversed through the cord. review 56 nerve injuries. Lyons et al. [42] reported good results regarding treatment-induced ulnar nerve injury after K cross fixation regardless of whether the nerve was removed, the nerve was probed or not. conservative treatment.

Ramachandran et al [43] reported a series of 37 radial, medial, and ulnar nerve lesions that appeared an average of 7.7 months after supracondylar fracture. Spontaneous recovery was seen in 27 people for a median of 7–8 months and 81% had excellent results. Exploration was needed in 10 patients, showing nine nerves in a continuum and a cross section. Ulnar neurolysis was required in six cases of entrapment in a fibrillar/chamber tunnel and four required neural grafts.

There was one patient with treatment-associated mast injury in this study due to cross-stapling (4.2%).



Figures 8: *C-D. 4th patient, boy 7.3 years.* ***A.*** *SCHF with Gartland type III;* ***B****. Open reduction of crossed pin;* ***C****. The nerve was found to be trapped by fibrous tissue behind the medial epicondyle;* ***D****. The ulnar nerve is separated from the fibrous tissue and transferred anteriorly.*

The patients presented with ulnar nerve palsy when they returned 10 weeks after surgery. (4th patient – Table 3) (Figures 8). He was seen at the clinic weekly, but they continued to have scratching in both thumbs and an area of decreased sensation in the little finger and under the skin. He underwent exploration of the ulnar nerve. The nerve was found to be trapped by fibrous tissue behind the medial spinous process. It is clear that the cords have been threaded through the sheath of the seemingly normal nerve at the proximal and distal ends of the tethered area. The nerve is released and placed anteriorly in the substance of the pronator teres. Hand and elbow function fully recovered 10 weeks post-operatively.

Vascular injury

Blakey et al. [41] reported long-term follow-up of 26 children with “pink and pulseless” hands, of which 23 had contractures and deformities of the forearm and hand. One patient had vascular probes over a 48-hour period but three patients, who were urgently probed, had no spasms. Delayed exploration was performed in 21 cases and identified vascular trapped in the fracture site in 9 cases and constricted scar tissue in 12 cases, decompression reverting to pulsation in all cases. case [41].

Vascular injury noted at the time of presentation required urgent fracture reduction. The absence of radial pulse in the perfused hand ('pink and warm') usually resolves spontaneously after fracture reduction and rarely requires surgical exploration [40]. Exploration, if necessary, should be performed by surgeons capable of repairing small vessels and routine tourniquets should not be used [41].

Several studies have reported an association between radial pulse loss and median nerve injury and this combination of clinical findings should warn of the possibility of neurovascular injury/bundle at the fracture site. bone.

Ischemic spasm mainly affects the fexor compartment due to prolonged ischemia but several studies have reported a low rate of contracture, in the absence of concomitant neurological damage.

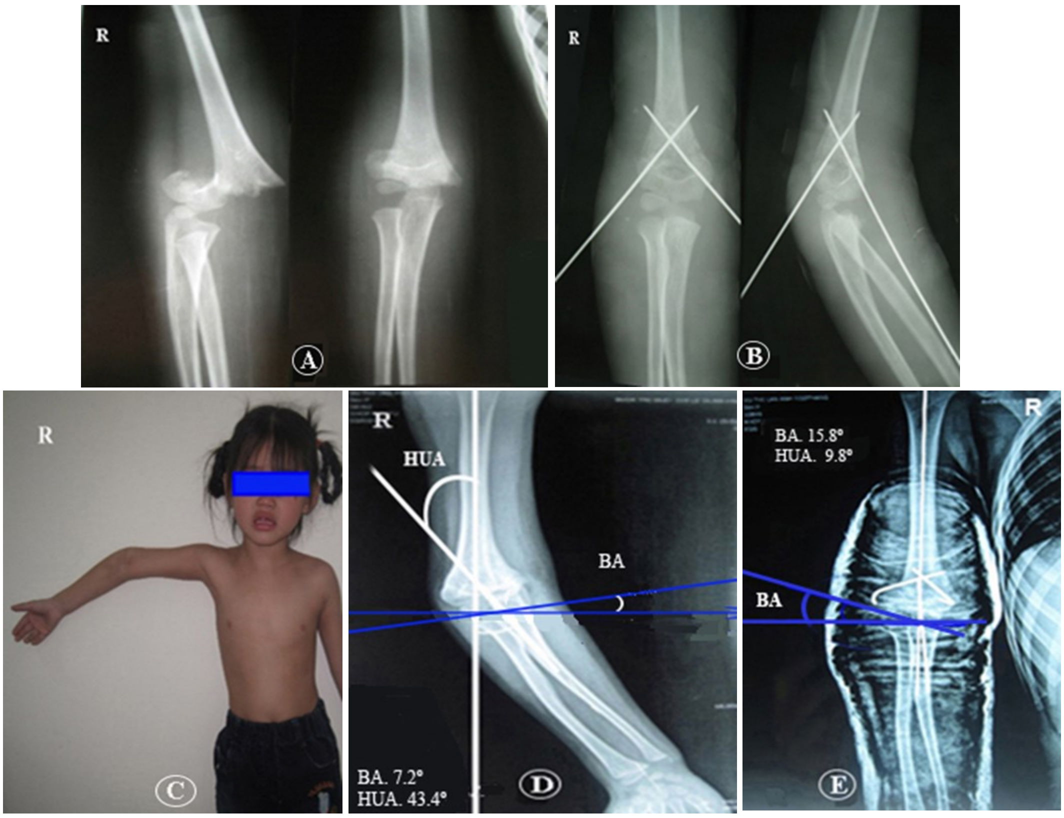
Mangat et al. [44] reported the results of 19 patients with perfused non-vascular hands, of which 11 were treated conservatively after closed manipulation. Delayed exploration was required in four subjects, of which three had median and/or interspinous nerve palsy prior to presentation. Urgent exploration was performed in eight patients and the brachial artery was ligated at the fracture site in six patients [44].

Rasool et al. [45] recommends exploration before manipulation of a posteriorly displaced supracondylar fracture with weak or absent pulse and mid-neurological symptoms where clinical signs of brachialis buttonhole exist, due to the proximity of the brachialis. closeness of the neural vascular bundle. The authors reported exploratory findings in 27 patients, with signs of median nerve injury in 22 patients at examination and neurovascular bundles noted to be proximal, tethered, or interspersed during examination. fracture site in all cases.

There was one patient who was punctured to the brachial artery during the surgery of this study (Patient 11, Table 3). After KW starting pin at lateral epicondyle, a fast-growing, soft-density mass appeared in the corresponding position of the KW, medial, and lower arm thirds. KW was withdrawn, tumor was grasped for 10 min, tumor did not enlarge. The brachial artery was examined and no bleeding was observed. After about 30 minutes, the operation continued and the KW was placed in the other direction. The patient was examined elbow and wrist with full function recovery, and no differences in average arm circumference, arm length, muscle endurance, or grip strength compared with the contralateral side, 54 months post-operatively.

Cubitus varus

The cause of cubitus varus remains uncertain. Most authors believe that central curvature is more a consequence of fracture misalignment than growth arrest. Angular and rotational distortions are believed to be responsible for internal curvature. A backward shift for a higher Baumann value indicates the internal curvature, while a backward shift for a lower Baumann value indicates an internal curve shape.



Figures 9: C-D *. 9th patient (Table 3), girl 5.8 years, right Cubitus varus, Postoperative crossed pin 42 months:* ***A.*** *SCHF with Gartland type III;* ***B****. Open reduction of crossed pin;* ***C****. The patient has right Cubitus varus;* ***D****. Preoperative radiographic humerus with BA. 7.2°, HUA. 43.4°;* ***E.*** *Wedges osteotomy at distal humeral and fix by crossed pin. Postoperative HUA 9.8° and BA 15.8°.*

The distal humerus of the humerus has limited remodeling potential. An eight to ten year old child has only 10% of the total height of the humerus remaining (Fig 9-C). While mild longitudinal and coronal deformities can be reconstructed in children < 4 years of age, rotational deformities cannot. In a study published by Moraleda et al [46] the prevalence of scoliosis in untreated type II fractures was reported to be as high as 26.1%. For that reason, the best way to avoid humeral fractures seems to be to achieve and maintain anatomical fracture reduction, with particular attention to reconstructing contralateral rotation of the humerus. Although parents consult for cosmetic reasons in most cases, several long-term complications are possible: late posterior rotator cuff instability; paralysis of the ulnar nerve; move the middle head of the triceps; and a higher risk of foreskin fracture. O'Driscoll et al. [47] asserted that medial torticollis leads to two biomechanical disorders: 1) the mechanical axis of the upper extremities is displaced inwards and, consequently, the load-bearing lateral ligament complex. pull up and become weaker; and 2) the triceps are displaced inward and the triceps force vectors are displaced resulting in the lateral (supine) clavicle above the ulna. Late ulnar nerve palsy with anterior dislocation of the nerve has been described [45]. Internal triceps fractures can occur due to internal displacement of the triceps as well as internal rotation of the distal humerus [48].

Several osteotomies have been proposed to correct internal scoliosis. Lateral wedge osteotomy is probably the most used osteotomy because of its ease of implementation; however, it did not resolve the internal rotation deformity and parents complained of cosmetic problems because the lateral condyle was still protruding. Other osteotomy has been advocated to avoid prominent lateral condyles [49].

In our opinion, since angular and rotational deformities should be resolved, complete osteotomy should be considered (palatal osteotomy or lateral closed wedge osteotomy allowing movement and resection). between bone fragments). distal) appears to be a powerful and reliable osteotomy method for achieving correction. [49] . In our opinion, it is difficult to correct midline curvature by laparoscopic surgery; For that reason, we advocate performing two complete osteotomies (one perpendicular to the diaphragm of the humerus and the other parallel to the humerus) so that resection can be performed. a lateral wedge to correct scoliosis concomitant with dislocation or distal flexion.

Cubitus valgus

Cubitus valgus is a rare complication of SCHF with a reported incidence of <1–3% and is more common following trauma/fracture in lateral foreskin fractures [50]. Similar to internal scoliosis correction, different surgical techniques have been reported for post-traumatic scoliosis including Ilizarov frame, palatal osteotomy, and stepwise osteotomy.

Conclusions

Supracondylar fractures of the humerus are a common problem in children, and surgeons sometimes have to deal with such fractures due to serious complications.

Conservative management is recommended for Gartland type I fractures and nondisplaced type II fractures. Closed reduction and percutaneous staples are preferred treatment options, but open retraction is still a good idea for Type IIB and III, IV. Positioning the internal pin by surgical technique must avoid nerve damage. The use of appropriate criteria is wise in managing these cracks; Prognosis in the event of complications or possible complications should be explained.

Limitations

Our study was retrospective, had a small number of patients, and had no control group. The surgical method is according to the classical technique, the outcome evaluation is also according to the standards already available. However, even though a large number of comparisons were not available, conclusions were drawn on the actual results obtained in the study.

Conflict of Interest

The authors declare no conflict of interest.

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