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Research Paper

Analysis of radiological alignment and functional outcomes of pediatric patients after surgery with displaced supracondylar humerus fracture: A cross-sectional study

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ABSTRACT

Introduction: Supracondylar humerus (SCH) fracture is the most common type of elbow joint fracture (50–70%) in children aged 3–10 years. Treatment of displaced SCH fracture are surgery using Kirschner wire. The outcome of SCH fracture in pediatric population can be assessed clinically and radiologically.
Methods: This study aims to analyze the correlation between radiological alignment and functional outcome in displaced SCH fracture in children under internal fixation. Study design was cross sectional with analytical approach. Medical records of children with displaced SCH fracture from January 2016 to December 2018 were taken for the study. The data included in this study were six weeks after removal of implant. The parameter of radiological alignment used in this study was Baumann's angle and the functional outcome based on Flynn's criteria. Data were analyzed using the Pearson Correlation test.
Results: Of the thirty samples enrolled in this study, 63.3% were boys. The mean age was 6.4 ± 2.0 years with peak incidence 5–6 years. Left side and non-dominant arm were more commonly injured with percentage of 63.3% and 70%. The mean of Baumann's angle and functional outcome were 73.5 ± 7.18 and 6.44 ± 4.7 degrees, respectively. There was a significant positive Pearson correlation (r = 0.491) between radiological alignment and functional outcome (p value = 0.006).
Conclusion: Radiological alignment had a significant positive correlation with functional outcome after surgery in displaced SCH patients.

1. Introduction

Supracondylar humerus (SCH) fracture is the most common type of elbow joint fracture (50–70% of the elbow joint fracture) in children [1,2]. Most occurs in the ages of 5–7 years old, more often in boys, and it predominantly involves non-dominant hands in almost all studies [2,3]. The Gartland classification modified by Wilkin is often used for the assessment of extension type SCH fractures based on radiographs. Gartland classification itself comprised of three types [4]. The main goal of surgical treatment of SCH fractures is to restore elbow joint movement, maintain anatomical position, avoid *cubitus varus* and iatrogenic nerve palsies [1,5–7]. Closed reduction percutaneus pinning (CRPP) is a treatment choice for SCH fractures often used in Gartland type I and II fractures, and open reduction internal fixation (ORIF) treatment is used in patients with open fractures, ischemic hand and failure of revascularization, failed closed reduction [4] (see Tables 1–7).

The outcome of SCH fracture can be assessed clinically and radiologically [6]. *Baumann's angle* is simple radiological indicator of adequate reduction in children SCH fractures [7,8]. Normal range from *Baumann's angle* is around 64–81° [9]. There are studies comparing CRPP and ORIF, with the results that CRPP has better functional and radiological results compared to ORIF in children

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Table 1
Flynn's criteria [11,14,20,23].

Result	Rating	Cosmetic factor: Carrying Angle loss (degrees)	Functional factor: Motion loss (degrees)
Satisfactory	Excellent	0–5	0–5
	Good	6–10	6–10
	Fair	11–15	11–15
Unsatisfactory	Poor	>15	>15

Table 2
Matrix variable indicator.

No.	Variable	Method	Scale
1.	Radiological alignment	Examination	Ratio
2.	Functional outcome	Physical examination	Ordinal

SCH fractures [10,11]. In addition, there are also studies that analyze radiological and functional results in SCH fractures using *Baumann's angle* and children's outcome data collection instrument (PODCI) [12]. However, there is still limited data regarding the correlation between functional and radiological results in SCH fractures [12]. In this study, the researcher wants to analyze the radiological and functional results of the SCH fracture using *Baumann's angle* and *Flynn's criteria* to find out whether *Baumann's angle* has an effect on functional outcome [9].

The articulation of distal humerus is divided into medial and lateral columns. The two columns are separated from a thin section of bone consisting of anterior coronoid fossa and olecranon posterior fossa. This relatively thin area is a weak part of the distal humerus and become the site of a SCH fracture [1]. SCH fractures are classified into three types based on the degree of *displacement* of the distal fracture according to *Gartland's Classification* [4,13–15].

Type I: Nondisplaced.
Type II: Displaced (with intact posterior cortex).
Type III: Displaced (no cortical contact).
- Posteromedial
- Posterolateral

In case there is a history of fall with an outstretched hand followed by pain and swelling in the elbow with loss of function of the upper limb, the emergence of pain plays a special role [16]. The most important part of a clinical examination is to establish and document a neurovascular examination. Each nerve must be assessed in both motor and sensory function, especially the anterior interosseous nerve [15,16] (See: Figs. 1-4).

Table 3
Characteristics of research samples.

Variables	n = 30 (%)	
Age	3–4	5 (16.7%)
	5–6	11 (36.7%)
	7–8	9 (30.0%)
	9–10	5 (16.7%)
Sex	Female	11 (36.7%)
	Male	19 (63.3%)
Side	Right	11 (36.7%)
	Left	19 (63.3%)
Dominant arm		9 (30.0%)
Non-dominant arm		21 (70.0%)
Technique	CRPP	12 (40.0%)
	ORIF	18 (60.0%)

Table 4
Correlation of *radiological alignment* and *functional outcome*.

Variables	Statistics	Radiological alignment (*Baumann's* Angle)
Functional outcome (loss *of* motion)	Pearson Correlation	0.491
	P	0.006
	N	30

Table 5
comparison of *Baumann's angle* based on fixation type.

Fixation	N	Mean	SD	p
CRPP	12	72.3	5.5	0.470
ORIF	18	74.3	8.4	

The presence of ecchymosis on the skin in the anterior distal portion of the humerus may indicate difficulty in reduction due to the presence of proximal fragments that lead anteriorly through the muscle *brachialis* and possibly the subcutaneous layer (*pucker sign*) (Fig. 5) [15–17] In type III fractures, the limbs form 2 angulation points that form the impression of an S position. Distally on the upper arm, there are protrusions on the anterior part that cover the distal end of the proximal part. The distal fragment is *displaced* proximally with the posterior olecranon becoming more prominent. Finally, distal fragments are flexed at the elbow, there are anterior hollows accentuating the S-shaped deformity (Fig. 5). [15,17].

Carrying angle and *Baumann's angle* are used to assess abnormalities on anteroposterior radiographs [19]. *Baumann's angle* used to evaluate the reduction of the fracture because it can maintain the estimation of the carrying angle (Fig. 6) [12,17]. On lateral film, the relationship between the anterohumeral line and the center of ossification of the capitellum (Fig. 7) must be examined. In the SCH fracture extension type, the capitellum is posterior to the anterohumeral line [17]. Normally this line must pass through the capitellum. In addition, fat pad sign that illustrates the presence of effusion in the joint can be found (Fig. 8) [1,17]. Gartland classification, based on lateral extraction, is widely used to assist in the management of SCH fractures [17].

The main objective of surgical treatment of SCH fractures is to restore elbow joint movement, maintain anatomical position, avoid heavy damage such as vascular damage and compartment syndrome and maximize appearance/cosmetics by avoiding the occurrence of *cubitus varus* and *iatrogenic nerve palsies* [1,5–7].

If the distal limb is ischaemic, action can be taken to restore the fracture fragment which should be performed in the emergency

Table 6
Functional outcomes based on flynn's criteria and fixation types.

Flynn's Criteria for loss of motion		CRPP[a]	ORIF[a]	Total	p
Satisfaction	Excellent	9	8	17	0.255
	Good	3	4	7	
	Fair	0	3	3	
Unsatisfactory	Poor	0	3	3	
Total		12	18	30	

[a] Fixation types.

Table 7
Functional outcomes based on flynn's criteria and type of fixation.

Variable	Fixation	N	Mean	SD	p
Loss of Motion	CRPP	12	4.1	2.0	0.026
	ORIF	18	8.0	6.5 6.5	

Fig. 1. SCH fracture gartland type I [4].

Fig. 2. SCH fracture gartland type II [4].

Fig. 3. SCH fracture gartland type III [5].

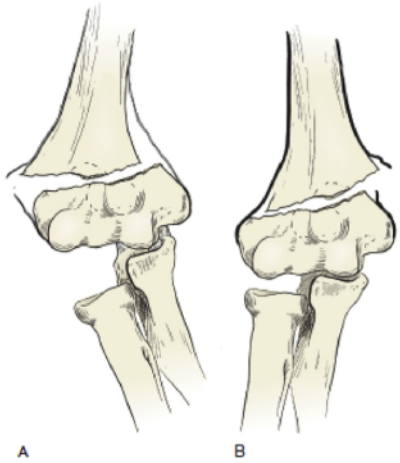

Fig. 4. SCH Fracture Gartland Type III, Posteromedially displaced fracture (A), Posterolaterally displaced fracture [1].

room. This can be done by pulling the elbow, correcting the deformity of the coronal plane and returning the proximal fragment posteriorly and the distal fragment anteriorly (Fig. 9).

Several treatment options are available for displaced SCH fractures (types II and III). The choice of methods is to maintain reduction until the fracture is healed including immobilization with cast, traction, percutaneous pin fixation. If reduction is not achieved by closed, so it means open reduction must be performed [1]. In extension-type fracture, the patient is positioned beside the operating table with the upper arm above the radiolucent table to assess the reduction using image transifier under general anesthesia (Fig. 10). While in flexion-type fractures reduction, closed reduction is obtained by longitudinal traction at the position of the elbow extension; the distal fragment is reduced by being directed toward the posterior part. All deformities corrected. After being reduced and confirmed, it is usually maintained by percutaneous pin fixation [1]. Imaging at the time of surgery enables the internal fixation by using percutaneous pins is relatively simple. Because fixation has predictable results with the fewest complications, this technique is for displaced SCH fractures [1].

Indications of open reduction are open fractures, inadequate reduction through closed reduction, or vascular injury. Open reduction through a mediolateral incision can provide adequate visualization of both fragments so as to enable accurate alignment to prevent *cubitus varus*. [15,20–22].

Baumann's angle is used as a universal guide to assessing fracture reduction in a child's supracondylar humerus [16]. *Baumann's angle* was assessed in subjects with exposed growth plates. By measuring the angle between the longitudinally drawn along the humerus and the line along the physical capitellar. The average value is between 64 and 81° [9].

The use of Flynn's criteria is a widely accepted method for assessing the results of SCH fractures and combining functional elements, such as range of motion and cosmetic elements with changes in carrying angle.

Complications of SCH fracture are divided into early complications and advanced complications. Early complications include vascular injury, nerve injury and compartment syndrome.

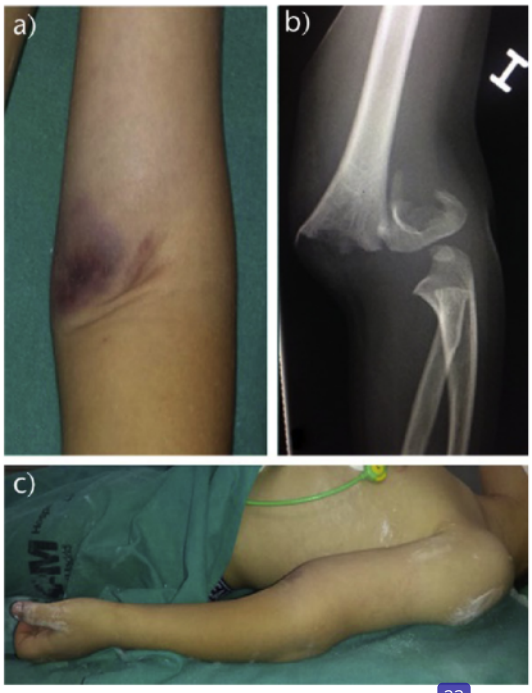

Fig. 5. Pucker sign - A skin fold in the colored antecubital fossa of a high-energy fracture that tears the brachialis and skin. b) Type III fractures that are highly *displaced*. When fractures are severely *displaced*, 'S-deformity' and skin wrinkles are usually seen, and the possibility of neurovascular injury and compartment syndrome should be considered; c) The so-called 'S-deformity' is seen in highly extension type fractures *displaced* [18].

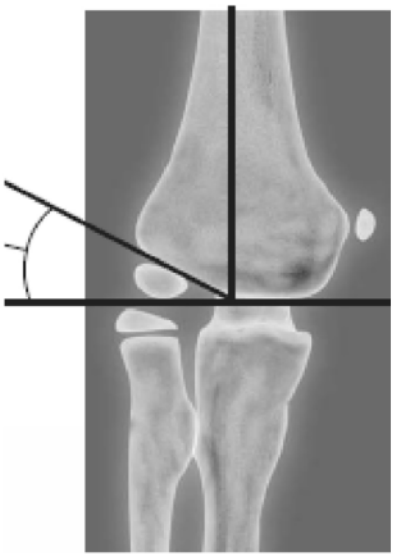

Fig. 6. *Baumann's angle* is obtained on anteroposterior radiography by measuring the angle between the perpendicular line to the longitudinal axis of the humerus and the line parallel to the capitellum growth plate [12,17].

Fig. 7. Humerus anterior lines. Vertical lines drawn directly on the anterior aspect of the distal humerus shaft must pass through the middle of the capitellum [3,17].

a Early complications

Vascular injuries are reported to range from 2 to 38% in gartland type III. Peripheral nerve injury ranges from about 10 to 15% of SCH fractures. The most frequent nerve injury related to the type of extension is the anterior interosseous nerve injury, although the median, ulnar and radial nerves can also be injured [4].

In cases where the pulse rate is not palpable, reduction is an *emergency*. In cases with poor circulation after reduction, vascular exploration and improvement of vascular are recommended [24]. *Neuropraxia* often occurs which will heal within 3–4 months. The injured nerve depends on the position of the *displaced* fragment [25].

The incidence of compartment syndrome that occurs in SCH fractures has decreased over the years due to improvements in the management of fracture management [5].

b Further complications

Malunion is a complication that often occurs in events of up to 50%.

This complication occur because of an inadequate reduction. SCH fracture does not cause growth stoppage. *Cubitus varus (gunstock deformity)* and *valgus* can cause functional limitations and cosmetic deformities [5,26].

2. Materials and methods

2.1. Patients

The design of this study was an analytic study with *cross sectional* approach. The research was conducted at Wahidin Sudirohusodo Hospital Makassar in October to November 2019. The population in this study were all medical records of pediatric patients with a diagnosis of SCH fracture after internal fixation using *kirschner wire*. Samples are entire populations that meet the selection criteria. The inclusion criterias are medical records of pediatric patients with SCH gartland type II and III fractures from January 2016 to December 2018, pediatric patients aged 3–10 years old, patients whose implants have been *removed* (CRPP and ORIF). The exclusion criterias are patients with open fractures, patients with neurological deficits, patients with trauma to the contralateral elbow (*contractures*), patients with *neurovascular injury*. Sample collection method use *total sampling*.

Variable Identification.

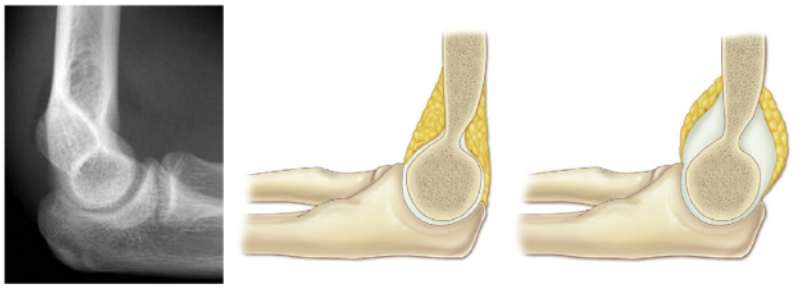

Fig. 8. Fat Pad Sign. A, Usually there are anterior and posterior fat pads. This structure can be seen as radiolucent adjacent to each other's cortex. B, there is an effusion, the fat pad will be lifted, thus creating a radiolucent "screen" [1,3].

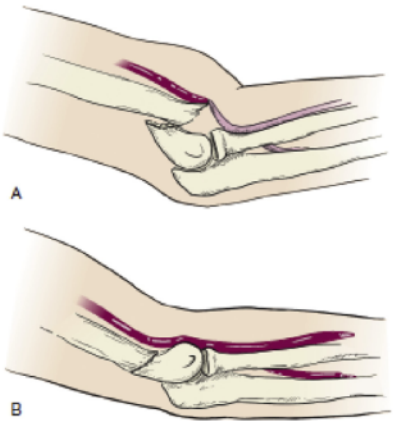

Fig. 9. A. Ischemic limb, B. Restoring position can reduce pressure on blood vessels and restore circulation [1].

2.2. Statistical analysis

Obtained from research subjects were processed using the *Statistical Package for Social Sciences* (SPSS) version 25 program with details as follows:

- Ratio-scale variables are presented in the form of mean ± standard deviations if the data distribution is normal or in the form of a median (minimum – maximum value) if the data distribution is not normal. Data normality test is done by Saphiro Wilk test. The significance limit is set at $p < 0.05$. Categorical scale variables are presented as n (%). Relationships between two ratio scale variables are analyzed using the Pearson correlation test if the data is normally distributed, and using the Spearman correlation test if the data is not normally distributed.

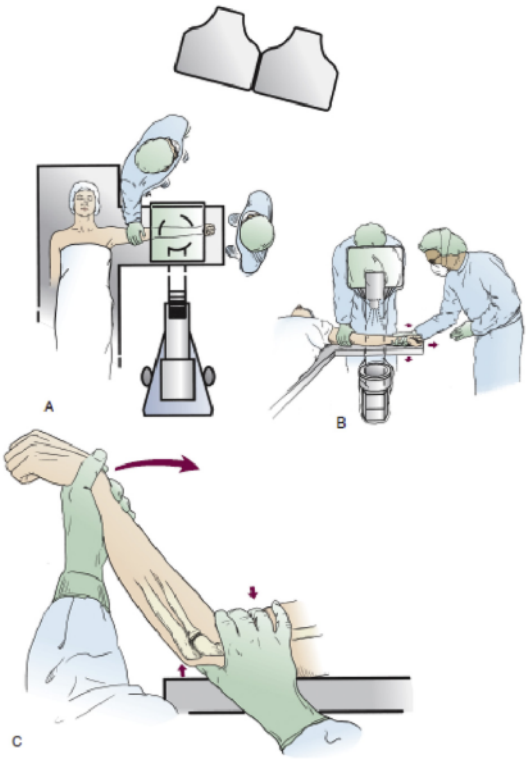

Fig. 10. Closed reduction technique by placing percutaneous pins on the SCH fracture. A. Position of the patient with *image transifier*, B. Initial action is carried out traction for correction of deformity (varus-valgus). C. The surgeon's dominant hand is used to reduce the fracture while the non-dominant hand flexes the elbow and pronation (fracture *displaced* posteromedial) or supination (fracture *displaced* posterolateral) of the forearm. The fingers on the dominant hand are used to press posteriorly to the proximal fragment while the posterior thumb presses the distal fragment anteriorly [1].

3. Results

From 30 patients recorded according to the inclusion criteria, the highest incidence was found at age 5–6 years as many as 11 people (36.7%). The most cases in men were 19 people (63.3%). The left side was injured more frequently in 19 cases (63.3% vs 36.7%) and more in non-dominant hands in 21 people (70.0%). More ORIF actions in this study were 18 people (60.0%) and 12 people (40.0%) with CRPP.

Based on *Pearson's correlation test* between *radiological alignment* and *functional outcome, the* coefficient ($r = 0.491$) with p value (0.006) was obtained.

Based on independent tests it was found that *Baumann's angle* was higher in ORIF (74.3) than in CRPP (72.3) but statistically not significant ($p > 0.05$).

Based on independent tests there is no significant relationship between functional outcome (based *flynn'scriteria*) with the type of

action ($p > 0.05$). Most of the subjects (27 of 30) in both groups of samples included in the satisfactory category. However, loss of motion significantly higher in ORIF than in CRPP, which is 8.0 compared to 4.1 ($p < 0.05$).

4. Discussion

SCH fracture is a fracture in the supracondillary part in the distal humerus above the condyle and the fracture line can be transverse, zigzag and oblique [27]. SCH fractures are more common in boys than girls. In our study, 63.3% were boys and 36.7% were girls. This result is in accordance with other studies [14]. In our study, fractures were more common on the left side 63.3% and 36.7% on the right side. This result is also in agreement with other studies [14]. In this study, the mean age for supracondillary fracture of the humerus ranges from 3 to 10 years with a peak incidence at 5–6 years. The average incidence is the same as the Ramsey and Griz studies, and Nacht et al. [14]. Based on studies from David C et al. Child Development and Pediatric Sport and Recreational Injuries by Age with the age of 5–6 years the highest incidence of injury at play [28].

There is a significant positive Pearson correlation coefficient ($p = 0.006$) between *radiological alignment* (*Baumann's angle*) and functional outcome scores (*Flynn's criteria*). The greater the *Baumann's angle* the higher the loss of motion score ($p < 0.05$).

The best results can be achieved with accurate reduction and stable fixation. However, the reduction accuracy is not the only factor that determines the functional outcome of a SCH fracture. Other factors such as physiotherapy and occupational therapy in SCH fractures also determine functional outcomes. The identification of these factors is very important to ensure good results in SCH fractures.

In our study, the average *Baumann's angle* in the CRPP and ORIF groups were 72.3 and 74.3°. There was no statistically significant difference ($p = 0.470$) between the type of fixation and *Baumann's angle*. In a similar study conducted in Nepal by Amin K et al. Showed the same results.

In our study, functional outcomes (*loss of motion*) in both the CRPP and ORIF groups were compared using *flynn's criteria*. The satisfactory functional results in both groups were 12 people and 15 people in CRPP and ORIF. We found no significant relationship in functional outcomes between CRPP and ORIF ($p = 0.255$). Other research results found that CRPP was proven to have much better functional results.

In this study, we found that CRPP have a much better loss of motion because it used x-ray *image transifier* in the operating room. CRPP was able to estimate the position of fragments (dislocation, angulation) from the results of the reduction compared to ORIF that does not use x-ray *image transifier*. [29] CRPP using *kirschner wire* and x-ray *image transifier* in SCH fractures in children is a good, fast, and effective technique especially for type III fractures. The advantages of CRPP include that the technique is fast, safe, no soft tissue dissection and minimal fracture hematoma disorders resulting in minimal risk infection, rapid healing and excellent results [2,30]. ORIF has greater risks of excessive callus formation and deep infection of the wound, so it can cause delayed in starting physiotherapy and get a good range of motion [2].

5. Conclusion

Radiological alignment anatomy (*Baumann's angle*) has a significant positive correlation with the functional outcome of patients after SCH fracture surgery in children ($p < 0.05$). *Baumann's angle* looks higher in ORIF than in CRPP, but it is not statistically significant ($p > 0.05$). There were no significant differences in functional outcomes in patients on CRPP and ORIF. Most of the subjects (27 of 30) in both sample groups fall into the satisfactory category. The subjects of this study were not operated on by a surgeon and radiological imaging was not taken by a radiographer. There should be other homogeneous studies (operated by one surgeon and imaging images taken by radiographers).

Ethical approval

This study was approved by the ethical board of Hasanuddin University of Makassar. Our patients has signed terms of consent to participate in the research of this original article. The institutional ethical committee has approved the publication of this original article.

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This study was funded independently.

Author contribution

M. Ihsan Kitta: Conceptualization, Methodology, Supervision, Data curation, Formal analysis, Validation, Resources, Funding acquisition, Project administration. **Yoyos Dias Ismiarto:** Conceptualization, Supervision, Formal analysis, Validation. **M. Ruksal Saleh:** Conceptualization, Supervision, Formal analysis, Supervision, Validation. **Muhammad Sakti:** Conceptualization, Supervision, Formal analysis, Supervision, Validation, Resources. **Moh. Asri Abidin:** Conceptualization, Data curation, Formal analysis, Investigation, Validation, Writing - Original Draft, Writing - Review & Editing, Visualization. **Luky Tandio Putra:** Conceptualization, Software, Data curation, Formal analysis, Investigation, Validation, Writing - Original Draft, Writing - Review & Editing, Visualization.

Declaration of Competing Interest

There are no conflicts of interest.

Guarantor

Luky Tandio Putra.

Research registration number

Researchregistry5630.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijso.2020.05.011.

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