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Differences in Carrying Angle, Baumann's Angle, Anterior Humeral Line and Dash Score between Children in the Age Group of Less than 5 Years and over 5 Years at 3 Months Post Open Reduction Internal Fixation Criss-Cross Wire Fracture Supracondylar Humerus Gartland Type III

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ABSTRACT

Introduction: **Supracondylar humerus fracture is one of the most found fractures in children. In addition to adequate fixation, the role of age differences in the clinical outcomes of operative treatment of supracondylar humeral fractures is still a matter of debate. This study aimed to compare the clinical and radiological outcome of surgery in cases of Gartland type III supracondylar humerus fracture.**

Materials and Methods: **This study used a cross-sectional design on the population of patient with Gartland type III supracondylar fracture. Patients were divided into 2 groups: age <5 years old (Group 1) and ≥5 years old (Group 2). The evaluation was carried out 3 months after surgery with open reduction internal fixation crisscross wire. The parameters assessed were Baumann's angle, carrying angle, and anterior humeral line, and Disabilities of the Arm, Shoulder, and Hand (DASH) Score. Difference between group were analyzed using the chi-square test.**

Results: **There were a total of 34 patients included in this study. Patients ≥5 years old had a 1.85 times greater chance to have a post-operative carrying angle of >15º (95% CI 0.993-3.474; p = 0.037) and 2.75 times greater chance to result in post-operative Baumann's angle >80º (95% CI 1,089-6,943, p=0.037). There were no significant differences in anterior humeral line (p=1) and DASH score (p=0.244) between groups.**

Conclusion: **The result of surgery in supracondylar fracture of the humerus over 5 years old tend to have worse radiological outcome (carrying angle and Baumann's angle) than patient younger than 5 years old. Thus, treatment of supracondylar fractures of the humerus aged more than 5 years requires more attention with adequate reduction and vigilance against complications that can affect the bone growth of pediatric patients.**

Keywords: Gartland type III fracture, outcome, open reduction internal fixation, pediatric.

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I. Introduction

Supracondylar fracture of the humerus is one of the most found fractures in children [1]. Treatment of a supracondylar fracture of the humerus requires adequate fracture reduction due to the presence of an active growth plate [2]. There is often a displacement of the fracture so that it requires operative treatment with internal fixation either in closed or open reduction. Even though it was treated surgically, there was a tendency for fracture complications in the form of cubitus varus deformity to be quite high. Parents of patients are often concerned about this condition due to cosmetic reasons. This requires special attention because of the high incidence of supracondylar fractures of the humerus [3].

Supracondylar fractures of the humerus account for 55% - 75% of all elbow fractures in children [1]-[3]. This can be caused by the laxity of the ligaments and thin bone structure in the supracondylar region of the humerus. Type III humeral supracondylar fracture according to Gartland, may be accompanied by neurovascular injury and cause complications such as malunion, elbow stiffness, and compartment syndrome [1], [4], [5]. The incidence of supracondylar fractures of the humerus Gartland type III is

quite high, reaching 39.3% of all cases. Cubitus varus is the most common complication in type III supracondylar fractures of the humerus. In the study by [6] the incidence of cubitus deformity was reported varus reached 26.1%. Approximately 25% of patients treated with open reduction surgery experience a varus deformity which is thought to be caused by inadequate reduction [7]. Type III supracondylar fractures of the humerus are generally treated with operative measures with closed reduction or open reduction techniques accompanied by percutaneous pinning in medial, lateral or cross positions. The results of the biomechanical study showed better stability when the pins were placed crosswise. The reduction was carried out under the guidance of the C-arm to control the results of the reduction. Closed reduction carries a risk of compartment syndrome and neurovascular injury. Open reduction is indicated when the fracture fails to reduce closed, there is trapped soft tissue, or when there is suspicion of a neurovascular injury. Open reduction has a higher risk of infection and stiffness. The main goals in the treatment of supracondylar fractures are to achieve anatomic reduction and maximal stability with adequate fixation [6].

In addition to adequate fixation, several studies have shown the role of age differences in the clinical outcome of operative treatment of supracondylar fractures of the humerus. From this study, there were differences in the incidence of complications in postoperative Gartland supracondylar humeral fractures type 3 at the age of less than 5 years compared to those over 5 years of age. Study in India reported that 84% of patients who experience varus malunion after supracondylar fractures were aged 5-10 years [8]. From a literature study, there were only a few references that compare clinical outcomes limited by certain age groups [9].

This study aimed to compare the result of surgery between age groups based on radiological outcomes using the Baumann's angle, carrying angle, and anterior humeral line; and clinical outcomes using the Disabilities of the Arm, Shoulder, and Hand (DASH) Score. The rationale for using the outcome parameter above is because the examination has been carried out a lot, has strong consistency and has been tested for validity.

II. Material and Methods

This is a cross-sectional study on the population of patients with Gartland type III supracondylar fractures. The research was conducted at Prof. dr. I.G.N.G. Ngoerah Hospital, Bali, Indonesia. The research ethics has been issued by the Research Ethics Commission at the Faculty of Medicine, UNUD / Prof. Dr. I.G.N.G Ngoerah Hospital Denpasar before the recruitment of subjects. The subjects has been explained regarding the purpose of the study and were asked to sign a written informed consent form before enrollment.

We included pediatric patients with Gartland type III supracondylar humerus fractures at the orthopedic polyclinic who underwent surgery with open reduction internal fixation (ORIF) criss-cross wire. Patients with a history of systemic disease, Gartland supracondylar fracture types I and II, pediatric patients over 14 years of age, and patients with neglected supracondylar fractures were excluded from this study. The samples were determined based on consecutive sampling.

Subjects were divided into two groups: age <5 years old (Group 1) and ≥5 years old (Group 2). The evaluation was carried out 3 months after surgery. The primary outcomes were radiological and clinical outcome. Radiological parameters were measured based on Baumann's angle, carrying angle (CA), and anterior humeral line (AHL). clinical outcome was assessed by DASH score.

Differences of radiological and clinical outcomes between age groups were analyzed using the chi-square test to obtain p value and Risk Ratio (RR). P-value <0.05 is considered as statistically significant. All the data analysis was performed using *Statistical Package for Social Sciences* (SPSS) for Windows® version 23 software.

III. Results

A. Patients Characteristics

There was a total of 34 pediatric patients with supracondylar humerus fracture included in this study. The characteristics of the subjects were shown in Table I.

TABLE I: Patients Characteristics

Variable	n (%)	Mean ± SD
Age (years)		5,18 ± 3
<5	17 (100%)	
≥5	17 (100%)	
Gender		
Male	21 (61,8%)	
Female	13 (38,2%)	
Side of Arm		-
Left	19 (55,88%)	
Right	15 (44,12%)	
CA		15,44 ± 3,93
5-15	14 (41,2%)	
>5-15	20 (58,8%)	
Baumann's Angle		76,23 ± 5,66
65-80	19 (55,9%)	
>80	15 (44,1%)	
AHL		-
Normal	34 (100%)	
Abnormal	0 (0%)	
DASH score		12.94± 3.01

AHL: Anterior humeral line; CA: Carrying angle; DASH: Disabilities of the Arm, Shoulder, and Hand.

B. Chi Square Test between Age Group and Carrying Angle

This analysis aimed to assess the difference of CA between age group. Patients ≥5 years old had a 1.85 times greater chance to have a CA of >15º postoperatively (95% CI 0.993-3.474; p = 0.037) (Table II).

TABLE II: Difference of Carrying Angle between Age Groups

Variable	Carrying Angle		P-value	RR (95% CI)
	>15^0	5-15º		
Age			0,037	1,85 (0,99-3,47)
≥ 5 years	13 (76.5%)	4 (23.5%)		
< 5 years	7 (41.2%)	10 (58.8%)		

C. Chi Square Test between Age Group and Baumann's Angle

This analysis aimed to assess the difference of Baumann's Angle between age group. Patients ≥5 years old had a 2.75

times greater chance to result in post-operative Baumann's angle >80º postoperatively (95% CI 1,089-6,943, p=0.037) (Table III).

TABLE III: DIFFERENCE OF CAYYING ANGLE BETWEEN AGE GROUPS

Variable	Baumann's Angle			RR (95% CI)
	>80⁰	65-80º	P-value	
Age			0,016	2,75 (1,089 – 6,943)
≥ 5 years	11 (64.7%)	6 (35.3%)		
< 5 years	4 (23.5%)	13 (76.5%)		

TABLE IV: DIFFERENCE OF AHL BETWEEN AGE GROUPS

Variable	AHL			RR (95% CI)
	Normal	Abnormal	P-value	
Age			1	-
≥ 5 Years	0	17 (100%)		
< 5 Years	0	17 (100%)		

AHL: Anterior humeral line.

TABLE V: DIFFERENCE OF DASH SCORE BETWEEN AGE GROUPS

Variable	DASH Score			RR (95% CI)
	Abnormal	Normal	P-value	
Age			0,244	2 (0,595 – 6,72)
≥ 5 Years	6 (35,3%)	11 (64,7%)		
< 5 Years	3 (26,5%)	14 (82,4%)		

DASH: Disabilities of the Arm, Shoulder, and Hand.

D. Chi Square Test between Age Group and AHL

This analysis aimed to assess the difference of AHL between age group. There is no significant difference of AHL between age group (Table IV)

E. Chi Square Test between Age Group and DASH Score

DASH score in the age group of ≥5 years has comparable results with the age group of <5 years. A p value = 0.244 was obtained, which means that there was no statistically meaningful difference (p>0.05) between the age group (Table V).

IV. DISCUSSION

A. Carrying Angle

In this study, it was found that age group ≥5 years old had higher tendency toward misalign CA. The results of this study are in accordance with the study of [10] which stated that there were differences in CA values in older age groups. This was also related to the study of [11] which identified the risk of deformity higher cubitus varus in the older age group. These angle changes may interfere with the cosmetics of the arms which are generally complained of by children's parents [12]. The study from Ganeshalingam measured average CA in a radiographic study conducted on 422 patients. Approximately 50 male and 50 female patients were divided into four age groups: newborn to 4 years, 5 to 11 years, 12 to 15 years, and adults. The mean CA was 15° in the newborn to 4-year-old cohort and increased slightly with age reaching 17.8° in adults [13].

Changes in the angle of the CA after a supracondylar fracture occur because of inadequate anatomic reconstruction due to displacement or repositioning, and possibly also due to disturbances in the growth of the distal end of the humerus. Previous retrospective study evaluated the causes of failure of adequate reduction in supracondylar humeral fractures treated operatively with Kirschner wires. The results of this study suggest that the stability of fracture fixation in supracondylar fractures in children depends on Kirschner wire pinning. Cross pinning provides a more stable fixation than lateral entry pins. Meanwhile, fracture pattern and reduction accuracy are not important factors in determining fixation stability [10]. Thus, proper operative technique is essential to maintain postoperative reduction including carrying angle, with the aim of preventing further complications.

In contrast, a study from [14], with a sample of 23 patients, found that patients in the age group > 5 years had better CA and humero-elbow-wrist (HEW) than those in the age group < 5 years. According to [10] CA values have a non-linear trend. Increases in CA are seen up to 15 years of age, commensurate with the age of epiphyseal closure around the elbow. The decrease in CA that is seen after the onset of puberty led us to speculate whether continued growth of the upper humerus and forearm might contribute to this decrease.

B. Baumann's Angle

This study found that age group ≥5 years old had higher tendency toward misalign Baumann's angle. This is in accordance with a study conducted by [15], which found an increase in Baumann's angle of 5.02 + 5.4° after operative action with pinning. The increase in the Baumann's angel is associated with inadequate anatomic reduction achieved. Study by [16], included 30 children with supracondylar fractures at the age of 5 years who underwent ORIF and closed reduction percutaneous pinning (CRPP) procedures. At a follow-up of 10 weeks, it was found that the average Baumann's angle in children who underwent the ORIF procedure was 74.3° and in children who underwent the CRPP procedure, it was 72.3°.

Baumann's angle in pediatrics that increases more than 80° tends to be accompanied by a varus deformity. A retrospective study related to post-operative Baumann's Angle was also conducted by [17], where this study looked for a correlation between the Baumann's Angle and the CA in children under 14 years of age with supracondylar fractures. In this study it was explained that postoperative Baumann's Angle measurements can estimate the amount of CA which is very important to prevent the occurrence of varus in patients [17].

The results of this study were not in accordance with the study obtained by [18] which stated that there was no effect of the age of the child at the time of surgery for a supracondylar humerus fracture on Baumann's Angle. Reference [18] studied Baumann's angle after fixation with 2 Kirschner wires in 20 children consisting of 10 children aged <5 years and 10 children aged ≥5 years. These results indicate that humeral supracondylar fracture surgery can be performed at any age.

C. Anterior Humeral Line

Reference [3] first delineates the AHL which can be pulled along the anterior humeral cortex. In most children, the AHL

passes through the middle third of the capitellum but may pass through the anterior third if the ossification center is small. The AHL is a radiographic index used to measure anterior-posterior displacement of supracondylar humeral fractures and the reduction in adequate post-treatment displacement on lateral radiographs. Anterior humeral line is used for assessment of pediatric elbow sagittal plane alignment in the surgical treatment of pediatric supracondylar humeral fractures. Identification of intraoperative AHL is a good indicator of achieving anatomical reduction. The anterior humeral line is said to be normal when it passes through the middle 1/3 of the capitellum [3].

This study found no differences in the normal AHL in the age group <5 years and ≥5 years after 3 months of surgery. All samples in this study showed a normal AHL after 3 months of surgery. This means that reduction in the sagittal plane can be achieved well and maintained after 3 months postoperatively. In a similar study by [2] of 124 children with supracondylar fractures of the humerus, a normal AHL was found in all samples aged ≥5 years (100%); normal in 11 (85%) of 13 children aged 4 years; normal in 11 (79%) of 14 children aged 3 years; normal in 15 (83%) of 18 children aged 2 years; and normal 17 (63%) of 27% of children aged < 2 years.

Study by [19] included 61 patients with Gartland Type III supracondylar fractures with an average age of over 5 years. The study obtained an average AHL value of 0.75, with variations ranging from 0.79 to 0.91 and from 0.70 to 0.75 [19]. Research on AHL in patients with Gartland Type III supracondylar fractures was also conducted by [20]. The population in this study was 101 children over 4 years old with an average age of 7.1 years. Samples were classified into 5 groups based on the location of AHL measured 3 months postoperatively [20].

Mean elbow extension angles did not differ significantly between the 5 groups ($p = 0.21$). However, patients with anterior AHL had a smaller elbow flexion angle (125.8 vs. 131.2, $p = 0.046$) and less total elbow range of motion (128.3 vs. 135.7, $p = 0.048$) compared with patients with AHL capitellum. When AHL affects the capitellum, angle of elbow flexion and range of motion of the elbow are significantly reduced in children with AHL that involves the anterior third of the capitellum [20].

D. Disabilities Questionnaire of the Arm, Shoulder, and Hand

DASH questionnaire is an instrument used as an indicator of disability in patients, with a range of 0-100. A value of 0 means no disability and above 0 indicates a disability. This study found an average DASH score of 0.35 ± 0.48 and as many as 22 (64.7%) children did not experience disabilities. There was no statistically significant difference in the DASH score of children < 5 years and ≥ 5 years. This result is similar to previous studies. A study conducted by [21], reported that in children in the age group less than 5 years with Gartland Type III supracondylar fractures of the humerus, the mean DASH score was 1.56 ± 3.13. Meanwhile, children in the age group over 5 years with a supracondylar fracture of the Gartland humerus Type III had an average DASH score of 2.68 ± 2.36. The research analysis test found no statistical difference from the DASH score based on the age group [21].

A study at a hospital in Africa by [22] stated that the age of surgery did not result on significant differences when assessed by QuickDASH Score. Based on the assessment of functional ability with the Quick DASH Score, 69.4% of patients had a Quick DASH Score within normal limits, while 25% of patients had a disability. However, it was stated that the Quick DASH Score is an objective assessment of functional ability. The patient's own quality of life can also be assessed subjectively with other assessment methods. The study found that one of the factors that plays a role in functional ability is the duration from the patient experiencing the injury until the patient gets treatment [22].

Assessment of functional ability in patients with Gartland type III supracondylar fractures of the humerus using the DASH score was also carried out in a study in Korea in 2017 by Wang, et al. A total of 154 patients with Gartland type III supracondylar humeral fractures were divided by age group, namely, less than 3 years, 3-6 years, 7-10 years and more than 10 years with an average patient age of 6.4 years. The overall average DASH score was 11.7 and for children aged 3 – 6 years it was 12.0, for 7 – 10 years it was 11.3, and the highest score was found in patients aged more than 10 years which was 12.4. Significance was determined using multiple regression analysis, where there were no statistically significant differences in the DASH score, both based on age, sex, BMI, fracture location and surgical technique [23].

V. Conclusion

In conclusion, the result of surgery in supracondylar fracture of the humerus over 5 years old tend to have worse radiological outcome (carrying angle and Baumann's angle) than patient younger than 5 years old. There was no difference between DASH score and anterior humeral line between difference age group. Thus, treatment of supracondylar fractures of the humerus aged more than 5 years requires more attention with adequate reduction and vigilance against complications that can affect the bone growth of pediatric patients.

Ethical Approval

The research protocol for Ethical Clearance from the Research Ethics Commission at the Faculty of Medicine, UNUD / Prof. Dr. I.G.N.G. Ngoerah Hospital Denpasar were submitted before the research were carried out. Subjects who met the study criteria were explained the purpose of the study and were asked to fill out written informed consent. Researchers have also attached a secondary data collection permit in the form of a medical record at Prof. Dr. I.G.N.G. Ngoerah Hospital Denpasar.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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