CHARACTERISTICS OF SUPRACONDYLAR FRACTURES IN THE PEDIATRIC POPULATION IN REGARD TO FRACTURE TYPE ACCORDING TO THE GARTLAND CLASSIFICATION

KARAKTERISTIKE SUPRAKONDILARNIH PRELOMA U DEČJEM UZRASTU U POREĐENJU SA TIPOM PRELOMA PO GARTLANDOVOJ KLASIFIKACIJI

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Abstract

Introduction. Supracondylar fractures are among the most common elbow injuries in the pediatric population and represent a significant therapeutic challenge. This study investigates the epidemiological and clinical characteristics of these fractures, with a particular focus on treatment approaches. **Materials and Methods.** A retrospective analysis was conducted on data from 254 patients treated at the Department of Traumatology, Clinic for Pediatric Surgery, from 2019 to 2023. The study was approved by the Ethics Committee of the Institute for Child and Youth Health Care of Vojvodina. Patients were divided into two age groups. Data collected included demographics, fracture type, treatment modality, treatment duration, comorbidities, complications, and outcomes. Statistical analysis was performed using *Jeffrey's Amazing Statistics Program* software, employing the chi-square test and Mann-Whitney U test. **Results.** Of the 254 patients, 56.69% were male and 43.31% female. Among school-aged children, the most common cause of injury was falling from a bicycle, while preschool-aged children most often sustained injuries during play. Type IIA fractures were more frequently associated with right arm injuries, whereas type IIIC fractures were common in the left arm injuries. Orthopedic reduction and percutaneous fixation using Kirschner wires were employed in 97.23% of cases. **Conclusion.** Supracondylar humerus fractures are more frequent in male children. No statistically significant difference was found in fracture incidence between preschool and school-age groups. Left-sided injuries were more common. Neurological complications were the most frequently observed, although no significant association was found between complication rates and fracture type.

Key words: Elbow Injuries; Humeral Fractures, Distal; Child; Fractures, Bone; Classification; Bone Wires; Sex Factors

Sažetak

Uvod. Suprakondilarni prelomi predstavljaju jedan od najčešćih preloma u zglobu lakta kod pedijatrijske populacije i izazov su u lečenju. Ova studija istražuje epidemiološke i kliničke aspekte ovih preloma, s posebnim fokusom na modalitete lečenja. **Materijal i metode.** Istraživanje je sprovedeno kao retrospektivna analiza podataka pacijenata sa suprakondilarnim prelomom humerusa lečenih na Odeljenju traumatologije Klinike za dečju hirurgiju od 2019. do 2023. godine uz dozvolu Etičke komisije Instituta za zdravstvenu zaštitu dece i omladine Vojvodine. Prema uzrastu, 254 pacijenta su podeljeni u dve grupe. Analizirani su demografski podaci, mehanizam povrede, tip preloma, način lečenja i komplikacije lečenja. Statistička obrada izvršena je korišćenjem softvera *Jeffrey's Amazing Statistics Program*, a razlike među grupama su testirane hi-kvadrat testom i Men–Vitnijevim U-testom. **Rezultati.** 56,69% ispitanika su bili muškog, a 43,31% ženskog pola. Dominantan uzrok povređivanja kod školske dece bio je pad sa bicikla, dok se kod predškolske dece povrede najčešće dešavaju tokom igre. Pacijenti sa povredama desne ruke su češće imali IIA tip preloma, dok su pacijenti sa povredama leve ruke imali IIIC tip. Kod 97,23% pacijenata načinjena je ortopedska repozicija i perkutana fiksacija pomoću Kiršnerovih igala. **Zaključak.** Suprakondilarni prelom humerusa kod pedijatrijskih pacijenata češći je kod muške dece. Nije bilo statistički značajne razlike u učestalosti preloma između predškolske i školske grupe. Dokazano je češće povređivanje leve ruke. Najčešće su neurološke komplikacije, bez statistički značajne povezanosti u odnosu na tip preloma.

Ključne reči: povrede lakta; suprakondilarni prelomi; dete; prelom kosti; klasifikacija; Kiršnerove igle; pol

Introduction

Supracondylar fractures are the most common type of elbow fracture in children, accounting for up to 70% of all elbow fractures and ranking second only to distal radius fractures in overall pediatric fracture incidence [1,2]. They represent approximately two-thirds of all fracture-related hospitalizations in the pediatric population [3], with and estimated incidence of 177.3 per 100,000 children. These fractures are more frequently observed in male children and typically involve the non-dominant arm [1]. The high incidence of supracondylar fractures in children is attributed to several anatomical and developmental factors, including increased laxity of the collateral ligaments, the relative immaturity of the supracondylar region of the humer-

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us, and the biomechanical vulnerability of the elbow joint during hyperextension [2–4]. Supracondylar fractures are classified by the mechanism of injury into two main types: extension and flexion [5].

Fractures in this study were categorized based on radiological findings using the modified Gartland classification system [6]. Due to the high frequency of Gartland type III fractures, we propose a supplementary subclassification to provide a more detailed assessment: Type IIIA – posteromedial displacement of the distal fragment, Type IIIB – posterolateral displacement of the distal fragment, Type IIIC – posterior cortical displacement less than 2 mm on lateral radiograph.

Despite being common, the treatment of supracondylar fractures remains a topic of debate. One major area of uncertainty lies in choosing between conservative and surgical management, especially for type II fractures, where treatment decisions depend on the degree of displacement, fracture stability, and the presence of neurovascular complications [7]. Another ongoing discussion concerns the optimal timing of surgical intervention – whether immediate operative management is superior to delayed treatment after a short observation period [8]. Additionally, attention must be given to the risk of postoperative complications such as residual deformity, joint contractures, and nerve injury [9].

The aim of this study is to analyze the characteristics of supracondylar humeral fractures in children treated at a single healthcare institution, with attention special focus on gender, age, side and mechanism of injury, treatment methods, and associated complications, in relation to the modified fracture classification.

Material and Methods

The retrospective study analyzed data from medical records of pediatric patients diagnosed with supracondylar humerus fractures who were hospitalized and treated at the Department of Traumatology, Clinic for Pediatric Surgery, Institute for Child and Youth Health Care of Vojvodina, between 2019 and 2023.

Patient data were retrieved from the *Heliant* health information system and the digital radiological database (Picture Archiving and Communication System – PACS).

A total of 254 patients were included in the study and categorized into two age-based groups: preschool children (1–6 years) and school-aged children (7 years and older). The following parameters were extracted from the medical records: demographic data, fracture type, treatment method, duration of treatment, essence of comorbidities, complications, and treatment outcomes.

Statistical analysis was performed using *JASP* software version 0.18.3.0. Descriptive statistics for numerical variables were reported as means and standard deviations, while categorical (nominal) variables were summarized as percentages and frequencies. Group differences in categorical (nominal) variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. The Mann–Whitney U test was used to compare numerical variables between groups. The predictive value of selected variables for the occurrence of neurological complications was assessed using binary logistic regression. A p-value < 0.05 was considered statistically significant. All results were summarized and presented in tabular form.

Results

A total of 254 participants with supracondylar humerus fractures were included in the study. Of these, 239 children (94.09%) were classified as extension-type fractures, and 15 (5.91%) as flexion-type **(Figure 1).** Of all participants, 56.69% were male and 43.31% were female. The age of participant ranged from 1 to 17 years. The preschool–age group comprised 49.21%, while 50.78% were older than 7 years **(Table 1).** There was no statistically significant difference in the distribution of fracture types by age group or sex (p > 0.05).

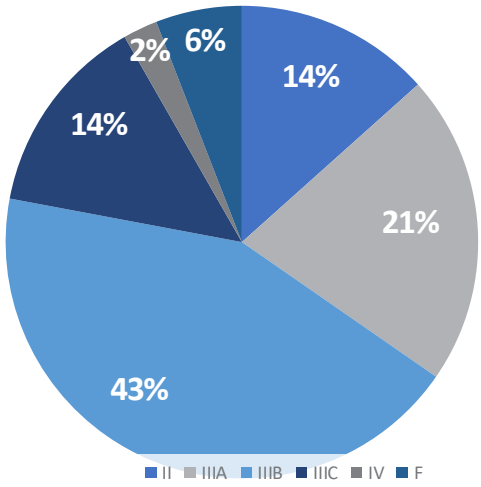

Figure 1. Distribution of supracondylar fractures

The common mechanism of injury in school-aged children was falling while riding a bicycle or engaging

Table 1. Distribution by gender and age group

Gender	
Male	144 (56.69%)
Female	110 (43.31%)
Age group	
Preschool	125 (49.21%)
School	129 (50.78%)

Table 2. Age distribution of injury mechanisms by patient gender

Injury Mechanism	Age group		Total	Fisher's exact	P
	Preschool	School			
Sports injury	3	14	17	19.973	0.001
	8.39%	8.60%	6.69%		
Unknown/other	55	61	116		
	56.81%	58.18%	45.66%		
Bicycle-related injury	12	21	33		
	16.30%	16.69%	12.99%		
Injury during play	47	31	78		
	38.53%	39.46%	30.71%		
Fall from the height	8	1	9		
	4.44%	4.55%	3.54%		
Traffic accident	0	1	1		
	0	0,50%	0.39%		
Total	125	129	254		
	100%	100%	100%		

in sports activities. In contrast, injuries in the preschool group most frequently occurred during play or due to falls from height. This difference in injury mechanism between age groups was statistically significant ($p < 0.05$) **(Table 2).**

Regarding the side of injury, left arm fractures were more prevalent (n = 144, 56.69%) compared to right arm fractures (43.31%).

Among the extension type fractures, 34 (13.39%) had type II fractures, 54 (21.26%) had type IIIA, 110 (43.31%) had type IIIB, 35 (13.78%) had type IIIC, and 6 patients (2.36%) had type IV fractures **(Table 3).**

Type IIA fractures were more frequently observed in right arm injuries, while type IIIC fractures were more common in left arm injuries. Although this difference was not statistically significant, the p-value was borderline ($p = 0.058$), warranting cautious interpretation.

Treatment most commonly involved closed (orthopedic) reduction followed by percutaneous fixation using Kirschner wires, performed in 97.23% of patients. Open reduction and Kirschner wire fixation were necessary in six cases (2.37%). One patient (0.40%) was treated with closed reduction and cast immobilization. There was no statistically significant association between the side of injury and the treatment method ($p > 0.05$). The Kirschner wire sizes ranged from 1.4 mm to 2.0 mm. Crossed pin placement was the most frequently used technique, applied in 226 cases (88.97%), while lateral pinning was used in 27 cases. No statistically significant association was found between the method of pin placement and the

Table 3. Fracture classification according to the side of the injured arm

Fracture classification	Side		Total	Fisher's exact	p
	Right arm	Left arm			
II	15	19	34	10.503	0.058
	13.64%	13.29%	13.44%		
IIIA	27	27	54		
	24.55%	18.88%	21.34%		
IIIB	49	61	110		
	44.55%	41.96%	43.31%		
IIIC	10	25	35		
	9.09%	17.48%	13.83%		
IV	0	6	6		
	0	4.20%	2.37%		
F	9	6	15		
	8.18%	4.20%	5.93%		
Total	110	144	254		
	43.31%	56.69%	100%		

severity of the fracture. Similarly, there were no significant differences in the time to cast removal or hardware extraction in relation to sex or age ($p > 0.05$).

Neurological complications were documented in 10 patients at initial emergency evaluation. Three patients exhibited median nerve (n. medianus) involvement, two had ulnar nerve (n. ulnaris) injuries, and two had radial nerve (n. radialis) deficits. Two children had combined deficits involving the ulnar and median nerves, and one child presented with a combination of ulnar and radial nerve involvement. The majority of neurological injuries occurred in type IIIB fractures (n = 5), followed by type IIIA (n = 4), and type IV (n = 1). All neurological deficits resolved over time, with complete recovery in all affected children within 6 to 12 months. No vascular injuries were recorded in the patient cohort.

Discussion

Supracondylar humerus fractures represent one of the most frequent and clinically significant pediatric fractures [1]. In our study, extension-type fractures predominated (94%), which aligns with existing literature [5,6]. Using our proposed subclassification of Gartland type III fractures into IIIA, IIIB, and IIIC, we found that type III accounted for 78.4% of all cases. Among these, type IIIB (posterolateral displacement) was the most common (43.3%), followed by type IIIA (posteromedial displacement, 21.3%), and type IIIC (minimal posterior cortical displacement, 13.8%). Type II fractures constituted 13.4% of cases, while type IV fractures – associated with multidirectional instability – were rare (2.4%). Flexion-type fractures accounted for 5.9% of the total. This high frequency of type III fractures is consistent with prior studies reporting that type III fractures comprise 60–70% of supracondylar fractures requiring hospitalization, while types I and II are less common (each about 15–20%) [10]. The elevated proportion of type III fractures in our cohort likely reflects a referral bias, as our institution serves as a regional trauma center. The rarity of type IV fractures also mirrors previous reports [6,11]. However, the predominance of subtype IIIB contrasts with some studies that report equal or greater frequencies of IIIA fractures [12, 13], suggesting the need for further research.

We observed higher overall incidence of fractures in boys (56.7%) compared to girls (43.3%), consistent with literature attributing this to increased physical activity and risk-taking behaviors in boys [1,14]. However, there was no statistically significant difference in the distribution of fracture types by sex ($p=0.623$), indicating that while boys are more likely to sustain fractures, the severity distribution across fracture types II through IV, including flexion types, is comparable between sexes. This aligns with prior studies noting sex as a risk factor for fracture occurrence but not for fracture type or severity [10,12,15].

The age distribution in our study showed a mean of 6.73 ± 2.52 years, consistent with the established peak incidence between 5 and 7 years [10,15]. Dividing patients into preschool (1–6 years) and school-age (7 years and older) groups, we found no significant difference in the distribution of specific Gartland fracture ($p = 0.129$). Although flexion-type and type IV fractures appeared more frequent in older children, and type IIIA fractures were more frequent in younger children, these differences were not statistically significant. This suggests that fracture severity is more strongly influenced by injury mechanics – such as fall height, angle, and impact force – than by age alone. Most studies highlight age as a general risk factor for fracture but not as a determinant of fracture severity [16]. Future research should examine fracture type distribution in broader age ranges, such as toddlers under three years or adolescents over 12, or analyze age as a continuous variable to identify subtle patterns.

Left arm injuries were more common (56.7%) than right arm fractures (43.3%), which is consistent with reports that supracondylar fractures more frequently affect the non-dominant arm [14]. Our analysis by Gartland fracture type revealed a borderline significant difference ($p = 0.058$), with type IIIA and flexion-type fractures more common on right arm injuries, and type IIIC and all type IV fractures observed exclusively on the left. These findings may reflect underlying biomechanical factors and warrant further investigation [17]. There was a statistically significant difference in the mechanism of injury between age groups ($p = 0.001$). Pre-school children typically sustained injuries from play or falls from height, while school-age children more often sustained fractures while riding bicycles or doing sports. Most injuries (94%) were caused by falls onto an outstretched hand (FOOSH), resulting in extension-type fractures [10, 18]. Higher-energy mechanisms, such as falls from height or bicycle accidents, are more likely to result in complete displacement (Gartland types III and IV), while lower-energy falls tend to cause less severe injuries (type II) [19]. This corresponds with the high proportion of type III fractures (78.4%) in our study.

Surgical management was the predominant treatment approach. Closed reduction and percutaneous fixation with Kirschner wires (CRIF) was used in 97.2% of cases, while open reduction (ORIF) was required in only 2.4%. Conservative treatment with cast immobilization (CRIM) was used in one patient (0.4%). Most surgical interventions were performed

within 24 hours, although patients initially managed conservatively who required surgery were treated after an average of 3.3 days later due to secondary displacement. This treatment pattern aligns with clinical guidelines recommending surgery for displaced fractures (Gartland types II-IV), and conservative management for stable, non-displaced fractures (type I) [10,20–23]. Cross-pin fixation (medial and lateral wires) was used in 88.97% of surgical cases, while lateral-only pinning was applied in 10.62%. There was no significant correlation between fracture type and pin configuration ($p > 0.05$), indicating that the choice of pinning technique was likely based on intraoperative stability and surgeon preference. Although cross-pin fixation offers greater rotational stability, it carries a higher risk of ulnar nerve injury, whereas lateral pinning is safer but potentially less stable for more severe fractures [10,20,24]. Our institution's preference for cross-pin fixation differs from emerging trends favoring lateral pinning for nerve safety. However, we observed no significant difference in outcomes, consistent with the findings of Kocher et al. [24].

The diameter of Kirschner wires ranged from 1.4 mm to 2.0 mm, as recommended based on patient age and bone thickness [13,20]. The average immobilization period was approximately 3.5 weeks (23–24 days), consistent with pediatric protocols. There were no statistically significant differences in immobilization duration by age or sex ($p > 0.05$). While not analyzed in our study, immobilization length may also correlate with fracture severity. Standard practice suggests 3-4 weeks of immobilization due to children's rapid bone healing, although recent studies explore shorter durations depending on fixation quality [25].

Neurovascular complications occurred in 3.9% of patients (10/254), most frequently involving the median and ulnar nerves, with fewer radial nerve injuries. Although anterior interosseous nerve palsy is often cited as most common in literature, our findings align with those of Tomaszewski et al. [15]. The relatively higher incidence of ulnar nerve injury may be associated with the prevalent use of cross-pin fixation [24]. Neurological deficits were observed only in displaced fractures, though no statistically significant association was found ($p = 0.174$), possibly due to small sample size. No vascular injuries were reported, a favorable result compared to literature noting radial pulse absence in 6-20% of cases and vascular compromise in 6-7% of displaced fractures [8,15,16]. This underscores the importance of timely surgical intervention and careful operative technique.

This study has several limitations. As a retrospective analysis, it was based on medical records, which may contain inconsistent or incomplete data, potentially affecting reliability. Conducted in a single institution, the findings may not be generalizable to other settings. Additionally, long-term outcomes – particularly regarding functional recovery and late complications such as malunion or neurological deficits – were not assessed. Variability in surgeon expertise and intraoperative technique was also not considered, which may influence outcomes. Future research should multicenter studies with prospective follow-up to evaluate long-term results and validate these findings in more diverse populations.

Conclusion

This study provides valuable insights into the relationship between age, gender, injury mechanism, and treatment modality in pediatric supracondylar humerus fractures.

A higher incidence of fractures was observed in male patients, indicating greater susceptibility compared to females. The side of the injury (left vs. right arm) and fracture type did not significantly influence treatment duration, suggesting that these factors are not major determinants in recovery time. However, the choice of treatment was strongly correlated with fracture type, with most displaced fractures managed successfully through closed reduction and internal fixation.

The exceptionally low rate of neurological complications underscores the effectiveness of the treatment approaches used at our institution.

In summary, the findings highlight the importance of a timely diagnosis and appropriate treatment selection, particularly for older patients. They also support the need for individualized treatment planning based on patient characteristics and fracture severity. Further research is essential to refine therapeutic protocols and ensure optimal long-term outcomes in the treatment of fractures.

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