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OUR EXPERIENCE IN TREATING MONTEGGIA FRACTURES IN PEDIATRIC POPULATION

NAŠA ISKUSTVA U LEČENJU PRELOMA TIPA MONTEGGIA U PEDIJATRIJSKOJ POPULACIJI

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Abstract

Introduction. Monteggia fracture-dislocations in children, defined by an ulnar fracture with associated radial head dislocation, are rare, accounting for approximately 1% of pediatric upper extremity fractures. This study aimed to evaluate the characteristics and treatment outcomes of these injuries, with particular attention to the clinical relevance of the Bado classification. **Material and Methods.** A retrospective case series was conducted at the Institute for Children and Youth Healthcare of Vojvodina over a five-year period. Twenty-two patients aged ≤ 18 years with confirmed Monteggia fractures were included. Data from medical records included demographics, injury mechanisms, Bado classification, treatment method, and outcomes. Statistical analyses employed Fisher's Exact Test, Analysis of Variance, and the Mann-Whitney U test. **Results.** The study included 22 patients, with a notable incidence of Bado Type IV fractures (31.8%). Diagnostic delays were most frequent in Bado Type III (40%) and IV (28.5%) injuries. Although no statistically significant association was found between Bado type and treatment outcomes, patient age significantly influenced the choice of surgical technique (p=0.024). **Conclusion.** Patient age was a significant determinant of the treatment strategy. While the Bado classification did not demonstrate predictive value for outcomes, it remains a valuable descriptive tool. Early diagnosis and appropriate management are critical to prevent long-term complications.

Key words: Fractures, Bone; Child; Ulna Fractures; Radius Fractures; Fracture Dislocation; Fracture Fixation; Treatment Outcome

Sažetak

Uvod. Monteđa (*Monteggia)* prelomi-dislokacije kod dece, karakterisane frakturom ulne uz dislokaciju glave radijusa, retke su i čine približno 1% pedijatrijskih fraktura gornjih ekstremiteta. Studija procenjuje karakteristike i ishode lečenja ovih fraktura, procenjujući relevantnost Badoove klasifikacije. **Materijal i metode.** Sprovedena je retrospektivna analiza slučajeva na Institutu za zdravstvenu zaštitu dece i omladine Vojvodine, u trajanju od pet godina. U studiju je uključeno 22 pacijenata, uzrasta do 18 godina, sa ovim tipom preloma. Podaci su prikupljeni iz medicinskih izveštaja, fokusirajući se na demografske podatke, mehanizme povrede, Badoovu klasifikaciju, metode lečenja i ishode. Korišćeni su Fišerov egzaktni test, analiza varijanse i Man-Vitnijev U-test za statističku analizu. **Rezultati.** Uzorak je obuhvatao 22 pacijenta sa značajnom incidencijom tipa IV fraktura (31,8%). Uočeni su problemi sa dijagnostikom, posebno kod tipova III (40%) i IV (28,5%). Nije pronađena značajna povezanost između Badoovog tipa fraktura i ishoda lečenja, ali je primećena korelacija između starosti pacijenta i izbora hirurške tehnike (p = 0,024). **Zaključak.** Uzrast pacijenta bio je značajan prediktor izbora hirurške strategije. Iako prognostička vrednost Badoove klasifikacije nije statistički potvrđena u ovom uzorku, ona ostaje neophodan deskriptivni alat. Rana dijagnoza i lečenje su imperativ za sprečavanje komplikacija.

Ključne reči: prelomi kosti; dete; prelomi ulne; prelomi radijusa; dislokacija preloma; fiksacija preloma; ishod lečenja

Introduction

Monteggia fracture-dislocations in children consist of an ulnar fracture with associated radial head dislocation, disrupting both the radiocapitellar and proximal radioulnar joints [1,2]. These injuries are rare, accounting for up to 5% of all elbow fractures [3] in general population, and only about 1% of all pediatric upper extremity fractures [4,5] – in stark contrast to the supracondylar fractures, which represent up to 70% of pediatric elbow fractures [6].

First described in 1814, the injury was later classified by Bado in 1967 into four types based on the direction of radial head dislocation [7]. Type I, the most common in children, involves anterior dislocation with an apex-anterior ulnar fracture [1]. Type II, more typical for adults, features posterior dislocation and apex-posterior ulnar fracture [8]. Type III is characterized by lateral dislocation with a metaphyseal ulnar fracture, while Type IV involves fractures of both the ulna and radius with anterior dislocation of the radial head [8] **(Figure 1).**

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Abbreviations

PIN – posterior interosseous nerve
CRIM – closed reduction and immobilization
ORIF – open reduction and internal fixation
OREF – open reduction and external fixation

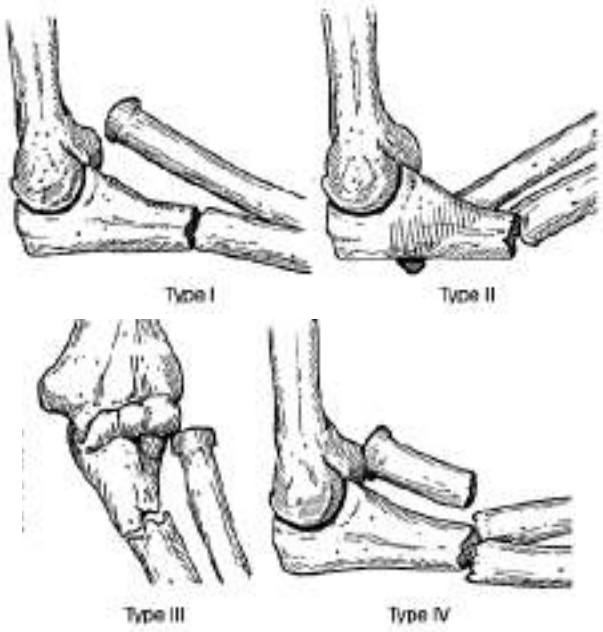

Figure 1. Aparicio Gomez A, Cadogan M. Bado classification. *Life in the Fast Lane* [Internet]. 2018 Oct [cited 2025 Oct 30]. Available from: https://litfl.com/wp-content/uploads/2018/10/Bado-Classification-of-Monteggia-Type-I-IV.png

Bado also introduced "Monteggia equivalents" for variant patterns [9], though this concept remains controversial [4,10]. Critics, such as Čepelík et al., have argued that many injuries previously termed "equivalents" – for example, those involving non-displaced proximal radius fractures – lack the same instability or treatment requirements as true Monteggia lesions and should not be classified as such [4]. While Bado Types I and III account for approximately 96% of pediatric cases [5], the injury's rarity contributes to frequent diagnostic oversight [1,5].

The Bado classification is essential for understanding the direction of instability, thereby guiding initial management. The primary treatment goal is anatomic restoration of ulnar length and alignment, which typically ensures reduction of the radiocapitellar joint [4]. However, management strategies range from conservative to surgical, depending on fracture stability [11,12]. Bado Type III fractures, in particular, are prone to failed closed treatment, with one study finding a significantly higher risk of such outcome for this type of injury [5]. Surgical fixation is indicated when stability cannot be maintained, with contemporary practice favoring early internal fixation if uncertain cases [5,11]. As Type III injuries are associated with a higher risk of complications like transient posterior interosseous nerve (PIN) palsy [4,5], the value of classification cannot be an absolute predictor of outcome.

The Letts classification introduced a pediatric-specific Monteggia equivalent – plastic deformation of the ulna with anterior radial head dislocation [14] – while Jupiter's classification expanded Bado Type II injuries into four subtypes based on the ulnar fracture morphology and associated radial head injury [8].

This study aims to analyze the relationship between Bado classification, treatment approach, and outcomes in a pediatric population.

Material and Methods

This retrospective case series was conducted at the Institute for Children and Youth Healthcare of Vojvodina in Novi Sad, a tertiary healthcare institution, covering the period, from January 1, 2019, to January 1, 2024. Ethical approval was obtained from the institutional ethics committee, and the study adhered to the principles of the Declaration of Helsinki.

Data were collected retrospectively from medical records and the hospital's electronic database ("Heliant"). A structured digital form (Google Forms) was used for data extraction and organization. Variables included demographic (age, sex), time from injury to admission and definitive treatment, injury mechanism, clinical and radiographic findings, Bado classification, treatment modality (surgical technique), hospital stay, immobilization duration, and complications. Patients aged 0-17 years, of both sexes with radiographically confirmed Monteggia fractures and complete documentation were included. Exclusion criteria were incomplete data, congenital radial head dislocation, and pathological fractures.

For analysis, patients were categorized by age (Early Childhood: 4–6 years; Middle Childhood: 7–10 years; Adolescence: 11–17 years) and mechanism of injury (fall, sports injury, traffic accident, direct blow, unknown).

Statistical analysis was conducted using IBM SPSS v25.0 (IBM Corp., Armonk, NY, USA). The significance level (alpha) was set at $p < 0.05$. Descriptive statistics were used for baseline characteristics, while Fisher's Exact Test analyzed analytical associations, ANOVA compared means across multiple groups, and the Mann-Whitney U test compared two groups.

Results

A total of 22 patients met the inclusion criteria. The basic demographic and clinical characteristics of the cohort are shown in **Table 1**. The mean age at injury

Table 1. Demographic and clinical characteristics of the analyzed cohort (N=22)

Characteristic	Number (N)	Percentage (%)
Total patients	22	100
Gender		
Male	12	54.5
Female	10	45.5
Age (years)		
Mean (SD)	8.0 (3.6)	–
Age Categories		
Early Childhood (4–6 yrs)	9	40.9
Middle Childhood (7–10 yrs)	9	40.9
Adolescence (11–16 yrs)	4	18.2
Mechanism of Injury		
Fall (low energy)	15	68.2
Sports Injury	3	13.6
Traffic Accident	1	4.5
Blow (direct trauma)	1	4.5
Unknown	2	9.1
Bado Classification		
Type I	7	31.8
Type II	3	13.6
Type III	5	22.7
Type IV	7	31.8

was 8.0 years ± 3.6 years; 12 (54.5%) were boys and 10 (45.5%) girls. The right elbow was affected in 12 (54.5%) and the left in 10 (45.5%) cased. Early and middle childhood categories were equally represented (each 40.9%). Bado types across the age categories are shown in **Table 2.** Bado Type I and Type IV were the most frequent, (each 7 cases or 31.8%), followed by Type III with 5 cases (22.7%) and Type II in 3 cases (13.6%). No statistically significant association was found between Bado type and age group (p=0.255). However, Bado Type III predominantly occurred in younger children (4 out of 5 cases, or 80%, were aged 4–6 years). The most common injury mechanism was a fall (low energy), recorded in 15 patients (68.2%), followed by sports injury in 3 patients (13.6%), traffic accidents (4.5%), and blow/direct trauma (4.5%) recorded 1 patient each, while in 2 cases the cause of injury was unknown. No statistically significant cor-

Table 2. Cross-tabulation of Bado type fracture distribution by age group (N=22)

Bado type	Early childhood (4–6 yrs)	Middle childhood (7–10 yrs)	Adolescence (11–16 yrs)	Total
Type I	1	3	3	7
Type II	1	2	0	3
Type III	4	1	0	5
Type IV	3	3	1	7
Total	9	9	4	22
Fisher's Exact Test	p=0.255			

Table 3. Association of Bado type fracture and injury mechanism (N=22)

	Fall (low energy)	Sports injury	Traffic accident	Blow (direct trauma)	Unknown	Total
Type I	4	2	0	1	0	7
Type II	2	0	0	0	1	3
Type III	4	0	0	0	1	5
Type IV	5	1	1	0	0	7
Total	15	3	1	1	2	22
Fisher's Exact Test	p=0.581					

Fisher's test did not show a statistically significant association (p=0.581).

Table 4. Distribution of operative techniques by Bado type fracture (N=21)

Bado type	CRIM	CRIF	ORIF/OREF	Total
Type I	3	1	3	7
Type II	1	1	0	2
Type III	4	1	0	5
Type IV	3	2	2	7
Total	11	5	5	21
Fisher's Exact Test	p=0.287			

*Note: One patient with Type II is missing due to unclear data on the technique.

Table 5. Average age of patients according to the applied operative technique

Operative technique	Number of patients (N)	Mean age (years)	Standard deviation (SD)
CRIM	11	6.3	2.8
CRIF	5	8.8	1.3
ORIF/OREF	5	11.8	3.8
ANOVA Test	F(2.18)=4.65	p=0.024	

relation was observed between Bado type and mechanism of injury (p=0.581) **(Table 3)**. The distribution of operative techniques by Bado fracture type is presented in **Table 4.** No statistically significant association was found between Bado type and the treatment method used. However, the minimally invasive CRIM technique predominated in Bado Type III fractures (4 out of 5 cases), while the most invasive techniques (ORIF/OREF) are most frequently applied in Types I and IV. Analysis of the average patient age for each surgical approach revealed a statistically highly significant trend (p=0.024) (**Table 5**). The least invasive technique (CRIM) was used in the youngest patients (mean age 6.3 years), whereas the most invasive method (ORIF/OREF) were employed in the oldest (mean age 11.8 years). Regarding the interval between injury and hospital admission, two Bado types stood out. Among patients with Bado Type III fractures, 40% (2 out of 5) experienced a delay in hospital admission – one was admitted four days after injury, and another after eighteen days. In the Bado Type IV group, 2 out of 7 patients (28.5%) were admitted one day after the injury, while in the Bado Type I group, one out of 7 patients (14.2%) had a one-day delay. Only patients with Bado Type II group fractures were admitted on the day of injury. Considering the time elapsed from injury to definitive management, 11 patients (50%) received treatment on the day of injury, 6 (27%) the following day, and 3 (14%) after several days. For 2 patients (9%), complete data on the exact timing of treatment were unavailable.

Discussion

Although other notable classification systems exist, such as those proposed by Letts and Jupiter [8,14], Monteggia lesions are almost universally described using the Bado classification, as it not only provides an anatomical description of the lesion but also facilitates understanding of the injury mechanism [4]. Monteggia lesions typically occur in children aged 4–10 years, often resulting from a fall on an outstretched hand [1,4]. Unlike adults, pediatric patients have open growth plates and may exhibit plastic deformation of the ulna [2]. Subtle greenstick or bowing fractures with radiocapitellar subluxation can be easily missed [15]. Acutely, these injuries impair forearm rotation and elbow stability. If untreated, chronic radial head dislocation may result in cubitus valgus, tardy ulnar neuropathy, and "mushroom" deformity of the radial head, ultimately causing functional limitation and painful radiocapitellar arthrosis [1,16].

The near-equal gender distribution in our cohort corresponds with the multicenter study by Ramski et al. [11]. The observed 31.8% incidence of Bado Type IV fractures is unusually high compared with large study of adult injuries by Weber et al. (3.1%) [17], pediatric series by Ramski et al. (4.5%) [11], and Čepelík et al., who reported a single case (<1%) in their cohort of 111 children [4]. This discrepancy may stem from the small sample size or referral bias due to our institution's tertiary status.

Prompt diagnosis requires a high index of suspicion, as any proximal ulnar fracture on plain radiographs should prompt careful evaluation of elbow alignment [8,18]. The key diagnostic feature is the loss of normal radiocapitellar alignment, where a line drawn along the radial axis must intersect the capitellum in all views [1]. This finding can be subtle, particularly in cases of plastic ulnar deformation, identifiable by the "ulnar bow sign" [1,15]. Consequently, Monteggia lesions are missed in up to 50% of cases

during the initial evaluation [15,19]. In our study, although the sample size was limited, the results partially align with these reports: 40% of patients in the Bado Type III group were diagnosed more than 24 hours after the injury, while in the Bado Type IV group, is the delay occurred in 28.5% of patients. However, due to the small cohort size, these findings should be interpreted with caution. Injuries not recognized within four weeks are considered chronic and are typically associated with functional deficits and deformity, making late reconstruction challenging and representing the most serious complication of this condition [1,16]. When diagnosed and treated promptly, pediatric Monteggia fractures generally have an excellent prognosis [5,21].

Statistical analysis of our cohort did not reveal a significant association between Bado type and any of the measured outcomes, suggesting that in this group, the Bado type itself was not a primary determinant of treatment success.

The most statistically robust finding was a strong correlation between patient age and the choice of operative technique (p=0.024). The least invasive method (CRIM) was applied in the youngest patients (mean age 6.3 years), whereas the most invasive approaches (ORIF/OREF) were used in the oldest (mean age 11.8 years). This observation is consistent with fundamental principles of pediatric orthopedic surgery, which emphasize treatment adaptation according to the bone remodeling potential [22].

This study has several limitations. The most important is the small sample size (N=22), which significantly limits statistical power. Additionally, as a tertiary referral center, our institution may treat a disproportionate number of complex cases, potentially explaining the atypical distribution of Bado types and limiting the generalizability of the findings.

Conclusion

This study provides valuable insights into the characteristics and treatment outcomes of Monteggia fractures in the pediatric population, reaffirming the clinical relevance of the Bado classification. While this classification remains the most widely used framework for describing these complex injuries, our findings suggest that it may not serve as a definitive predictor of treatment outcomes. The relatively high incidence of Bado Type IV fractures in our cohort, along with the observed diagnostic delays, underscores the persistent challenges in the timely recognition and management of Monteggia lesions. Furthermore, the significant correlation between patient age and the choice of surgical intervention highlights the importance of developmental factors in treatment planning. Despite the study's limitations – most notably the small sample size and potential referral bias – these results emphasize the need for greater awareness and early evaluation of suspected Monteggia fractures to prevent long-term complications. Future research involving larger, multicenter cohorts will be essential to further assess the influence of the Bado classification on treatment strategies and outcomes in pediatric Monteggia fractures.

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