

PROXIMAL HUMERUS FRACTURES IN THE PEDIATRIC POPULATION

PRELOMI GORNJEG OKRAJKA RAMENICE U PEDIJATRIJSKOJ POPULACIJI

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Abstract

Introduction. Pediatric fractures can impose temporary activity restrictions and, in some cases, result in lasting functional limitations. The study examines the distribution of age and gender among affected patients, mechanisms of injury, duration of immobilization, and the prevalence of surgical treatment methods in children with proximal humerus fractures. **Material and Methods.** This retrospective study, conducted between 2016 and 2023, included 249 children (aged 0-17 years), both male and female, with proximal humerus fractures. Statistical analysis was performed using the Mann-Whitney test, Chi-square (X^2) test, and post-hoc tests. **Results.** Among the 249 participants, 25 required surgical treatment. The surgical intervention rate increased with age, from 5.1% in children under 7 years to 17.4% in those over 12. Gender did not significantly influence the likelihood of surgical treatment ($p > 0.05$). Traffic accidents were significantly more common in the surgical group (30% vs. 3.7%), suggesting a correlation between high-impact trauma and the need for surgery. Immobilization duration was significantly shorter in non-surgical patients compared to those who underwent surgery ($p < 0.05$). The average hospital stay for surgically treated patients was four days, with treatments including various internal fixation methods. **Conclusion.** Proximal humerus fractures in children occur equally in both sexes, predominantly affecting those aged 7 to 12 years. Falls represent the most common injury mechanism, while traffic-related trauma is more frequently associated with surgical cases. Approximately 10% of children require surgical intervention, particularly older patients due to reduced bone remodeling capacity. Elastic nails and Kirschner wires are effective fixation methods. Further studies should stratify patients based on demographics and fracture classification to optimize treatment strategies and evaluate long-term outcomes.

Key words: Humeral Fractures; Shoulder Fractures; Child; Risk Factors; Orthopedic Procedures; Treatment Outcome

Introduction

Fractures are a common occurrence in childhood, with approximately half of all children reaching adulthood without experiencing a single fracture (60% of girls and 49% of boys) [1]. Pediatric fractures often result in temporary activity restrictions and, in some cases, may lead to persistent functional limitations [2].

Sažetak

Uvod. Prelomi kod dece mogu dovesti do privremenih ograničenja aktivnosti i do trajnih funkcionalnih ograničenja. Studija je ispitivala starosnu i polnu distribuciju pacijenata, mehanizme povrede, trajanje imobilizacije i prevalenciju hirurških metoda lečenja preloma proksimalnog humerusa kod dece. **Materijal i metode.** Retrospektivna studija, sprovedena od 2016. do 2023. godine, obuhvatila je 249 učesnika uzrasta od 0 do 17 godina, oba pola, koji su zadobili prelome proksimalnog humerusa. Statistička analiza je izvršena korišćenjem Mann-Vitnijeveg testa, hi-kvadrat (X^2) testa i post-hok testova. **Rezultati.** Od 249 učesnika, 25 je lečeno hirurški, sa stopom povećanja sa 5,1% kod onih ispod sedam godina na 17,4% kod pacijenata starijih od 12 godina. Pol nije značajno uticao na stope hirurškog lečenja ($p > 0,05$). Saobraćajni traumatizam je bio češći mehanizam povređivanja u hirurškoj grupi (30% prema 3,7%), što ukazuje na težinu povreda koje su zahtevale operaciju. Nehirurški pacijenti su imali kraće trajanje imobilizacije od hirurških pacijenata, sa značajnom razlikom ($p < 0,05$). Hirurški pacijenti su prosečno boravili u bolnici od četiri dana, uz operacije koje su uključivale različite metode unutrašnje fiksacije. **Zaključak.** Prelomi proksimalnog humerusa kod dece se javljaju podjednako po polu, najčešće kod dece uzrasta od sedam do 12 godina. Padovi su najčešći mehanizam povrede, dok je saobraćajna trauma češća u hirurškim slučajevima. Oko 10% pacijenata zahteva operaciju, prevashodno starija deca zbog smanjenog kapaciteta remodeliranja. Efikasne hirurške metode uključuju elastične klinove i Kiršnerove igle. Buduća istraživanja bi trebalo da klasifikuju pacijente prema demografiji i tipu preloma kako bi se optimizovao tretman i procenili dugoročni ishodi.

Ključne reči: prelomi humerusa; prelomi ramena; dete; faktori rizika; ortopedske procedure; ishod lečenja

Proximal humerus fractures in children typically occur following a fall onto the shoulder or an outstretched arm. The most common mechanisms include falls from height, sports-related injuries, traffic accidents, and, less frequently, pathological fractures.

These fractures exhibit a considerable capacity for remodeling due to the proximal humeral growth plate, which contributes approximately 80% to the

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Abbreviations

CRIM – Closed Reduction Immobilization
CRIF – Closed Reduction Internal Fixation
ORIF – Open Reduction Internal Fixation

longitudinal growth of the humerus [3]. The proximal humeral physis closes between the ages of 14 and 17 years in females and between 16 and 18 years in males. Consequently, the closer a patient is to physeal closure, the lower the bone's remodeling potential [4].

The management of proximal humerus fractures in pediatric patients remains a topic of debate. According to Neer and Horwitz [5], grade I and II proximal humerus fractures in children and older adolescents are generally treated non-operatively. Immobilization is typically maintained for 3 to 4 weeks, with the duration determined by clinical and radiographic assessments of healing [6]. However, non-surgical management is not recommended for patients with open Neer and Horwitz grade I and II fractures, vascular injuries, or polytrauma [7].

Unlike in adults, where the criteria for surgical intervention are well established, the indications for operative treatment in pediatric patients remain controversial. Some trauma surgeons advocate for conservative management even in cases with significant displacement, citing the high remodeling potential of the proximal humerus epiphysis, which may obviate the need for surgery [8]. Conversely, it is argued that in children with less than two years of remaining growth, fractures with displacement exceeding 40° may not undergo sufficient remodeling, warranting surgical intervention [4].

Treatment decisions are primarily guided by the patient age, fracture displacement, and the bone's remodeling potential. Nonoperative management is generally preferred for younger patients and those with minimally displaced fractures, whereas surgical intervention is considered for older children with significantly displaced fractures.

An individualized approach is essential to determine the most appropriate treatment strategy. Various fixation methods are utilized in surgical management, including Kirschner wires [9], cannulated screws [10], elastic intramedullary nails [11], external fixators [12], and locking plates [13], with the latter typically reserved for patients nearing skeletal maturity [14]. However, surgical treatment carries potential risks, such as infection and neurovascular injury [15–17]).

This study aims to analyze the age and gender distribution of pediatric patients with proximal humerus fractures, identify the predominant mechanisms of injury, assess immobilization duration based on treatment modality, and evaluate the prevalence of surgical interventions.

Material and Methods

This study was approved by the Ethics Committee of the Institute for the Health Care of Children and Youth of Vojvodina. Conducted retrospectively from 2016 to 2023, it included 249 pediatric patients (aged 0 to 17 years) of both sexes who sustained proximal humerus fractures and provided consent for participation. The only exclusion criteria were open fractures and incomplete medical records. Participants were categorized into two groups: the non-operative treatment group (n = 224) and the surgical treatment group (n = 25).

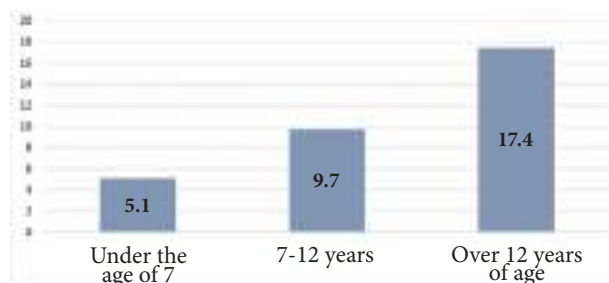
Among non-operatively treated patients, 127 (57%) were female and 97 (43%) were male. Fractures affected the left arm in 122 (54.5%) and the right arm in 102 (45.5%) cases. In the surgical group, 12 patients (48%) were female and 13 (52%) were male, with 15 (60%) sustaining fractures in the left arm and 10 (40%) in the right arm. The mean age of non-operatively treated patients was 9.12 years, whereas the mean age of operatively treated patients was 10.72 years.

Conservative treatment involved Desault's immobilization was following outpatient radiographic evaluation and fracture confirmation, with subsequent follow-up by an orthopedic surgeon. Patients requiring surgical intervention were admitted after diagnostic assessment and surgical indication confirmation. Procedures were performed under general anesthesia using one of the following techniques: Closed Reduction Immobilization (CRIM), Closed Reduction Internal Fixation (CRIF), or Open Reduction Internal Fixation (ORIF). Postoperatively, Desault's immobilization was applied when necessary, and all patients continued follow-up under orthopedic supervision.

All patients received treatment and follow-up at the same hospital, with clinical data recorded at each visit. Statistical analysis was conducted using the JASP software package. The Mann-Whitney test, Chi-square (X^2) test, and post-hoc tests were employed for data analysis.

Results

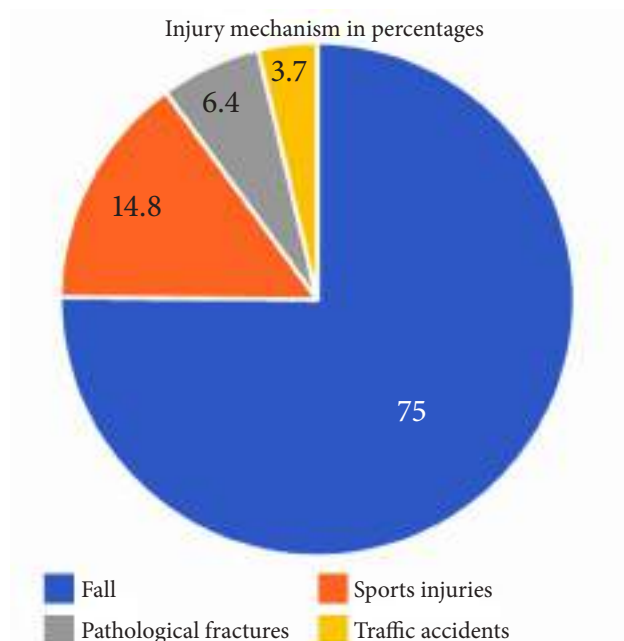
Of the 249 participants, 25 (10.04%) underwent surgical treatment. The proportion of patients requiring surgery increased with age: 5.1% of patients younger than 7 years, 9.7% of those aged 7–12 years, and 17.4% of patients older than 12 years underwent operative treatment (**Graph 1**). Among the 139 female participants, 12 (8.6%) underwent surgical treatment, while 13 (11.8%) of the 110 male participants required surgery. There was no statistically significant difference in surgical treatment rates between genders ($p > 0.05$).



Graph 1. Percentage of patients treated surgically by age group

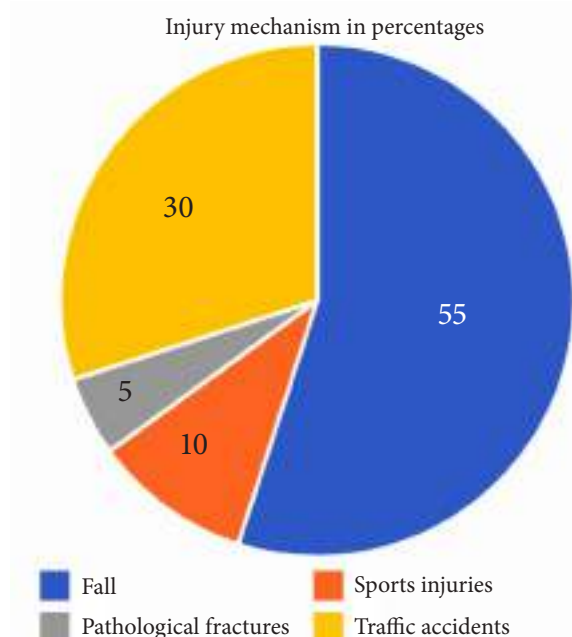
Among the 224 patients treated non-operatively, 127 (57%) were female, and 122 (54.5%) had fractures of the left arm. In the surgically treated group ($n = 25$), 12 (48%) were female, and 15 (60%) had fractures of the left arm. There was no statistically significant difference ($p > 0.05$) in gender distribution or affected limb between the surgical and non-surgical group, although left-sided fractures were more frequent in both.

In the non-operatively treated group, 38 (17%) patients were older than 12 years, 130 (58%) were aged 7-12 years, and 56 (25%) were younger than 7 years. In the surgically treated group, 8 (32%) were older than 12 years, 14 (56%) were aged 7-12 years, and 3 (12%) were younger than 7 years. While there was no statistically significant difference ($p > 0.05$) in the age distribution between the surgical and non-surgical groups, the surgical group had a higher proportion of older patients and a lower proportion of younger patients. In both groups, the majority of patients were in the 7-12 years age category.



Graph 2. Injury mechanism in the non-surgically treated group

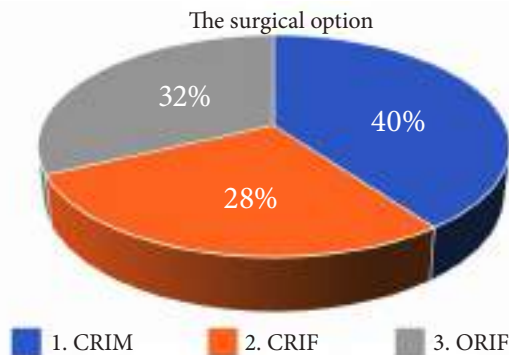
In the non-operatively treated group, the most common cause of fractures was falls (75%; $n = 142$), followed by sports injuries (14.8%; $n = 28$), pathological fractures (6.4%; $n = 12$), and traffic accidents (3.7%; $n = 7$) (**Graph 2**). In the surgically treated group, falls remained the most frequent cause (55%; $n = 11$), but traffic accidents were significantly more prevalent (30%; $n = 6$), followed by sports injuries (10%; $n = 2$), and pathological fractures (5%; $n = 1$) (**Graph 3**). A statistically significant difference ($p < 0.05$) was observed in the mechanisms of injury between the two groups. Post-hoc tests indicated a highly statistically significant difference in the proportion of traffic-related fractures, which were markedly higher in the surgical group.



Graph 3. Injury mechanism in the surgically treated group

Among non-operatively treated patients, the average duration of immobilization was 22.3 days, whereas surgically treated patients required immobilization for an average of 34.3 days. The difference in immobilization duration was statistically significant ($p < 0.05$), with surgically treated patients requiring longer immobilization periods.

All non-surgical patients were managed in an out-patient setting, whereas surgically treated patients required hospitalization, with an average hospital stay of 4 days. Among the 25 surgically treated patients, Closed Reduction Immobilization (CRIM) was utilized for 10 patients, Closed Reduction Internal Fixation (CRIF) for 7 patients, and Open Reduction Internal Fixation (ORIF) was used for 8 patients (**Graph 4**). Of the 15 patients who underwent internal fixa-



Graph 4. Surgical technique used in the operated group

tion, 8 were fixed with elastic nails, 6 with K-wires, and 1 patient with a locking plate.

Discussion

Upper extremity fractures are the most common fractures in children, accounting for approximately 80% of all pediatric fractures, with distal radius and supracondylar humerus fractures being the most frequent [18]. Proximal humerus fractures, however, are relatively rare, constituting about 2% of all fractures in children [19].

The optimal management of pediatric proximal humerus fractures remains controversial, with no clear consensus on indications for surgical treatment despite multiple proposals over the past 30 years [6, 8, 11, 12, 14]. In adults, approximately 15.7% of these fractures are managed surgically [20], whereas in children, due to open growth plates and the potential for remodeling, surgical intervention is less common. In our study, 10.04% of patients underwent surgery, aligning with previous studies reporting surgical rates between 10% and 17.3% [21, 22]. Kim et al. [23] found that older adolescents were twice as likely to undergo surgery compared to younger adolescents (19.8% vs. 8.5%, $p < 0.01$), a finding consistent with our study, where a significantly higher proportion of patients older than 12 years required surgery.

In our cohort, 8.6% of female and 11.8% of male patients underwent surgery, slightly higher than the 7% of boys and 5% of girls reported by Jakobsen et al. [18]. Despite this variation, both studies suggest a 40% higher likelihood of surgery in male children. Kim et al. [23] also observed a higher frequency of surgical treatment in boys (13.4% vs. 9.4% in girls). The increased rate of surgery in their study may be explained by the inclusion of only patients older than 10 years, involving group with a higher proportion of closed growth plates.

Although most patients in our study were treated non-operatively, 10 patients (4%) underwent closed

reduction under general anesthesia without fixation, while 15 patients (6%) required surgical fixation. These findings are comparable with those of Hannonen et al. [19], who reported 1% undergoing closed reduction under general anesthesia and 8% requiring surgical fixation.

Our study found that 32% of surgically treated patients required open reduction, a lower percentage than the rates reported by Bahrs et al. [17] (52%), Pavone et al. [24] (61%), and Binder et al. [22] (47.5%). Bahrs et al. noted that periosteum or biceps tendon entrapment often prevents closed reduction. Pahlavan et al. [25] reported biceps interposition at the fracture site in 9.4% of cases, highlighting this as a common cause of failed closed reduction.

Among the 25 surgically treated patients in our study, 12 (48%) were female, and 15 (60%) had left arm fractures, closely aligning with Pavone et al. [24], who reported 46.1% female patients and 57.7% left arm injuries. Other studies report a similar gender distribution in surgical cohorts, ranging from 44% to 60.4% female patients [26, 27].

The average age of non-operatively treated patients in our study was 9.12 years, compared to 10.72 years for those treated operatively. Pavone et al. [24] reported an average surgical age of 12.8 years, while Canavese et al. [26] found 11.1 years, both consistent with our findings. Binder et al. [22] observed an average surgical age of 11.3 years and non-surgical age of 9.9 years, noting a statistically significant difference. These findings reinforce that older patients (over 12 years) are more likely to require surgery, whereas younger patients (under 7 years) rarely undergo operative treatment.

In our surgically treated group, 11 (55%) fractures resulted from falls, 2 (10%) from sports injuries, 1 (5%) from pathological fractures, and 6 (30%) from traffic accidents. These findings are comparable to Pavone et al. [24], who reported falls in 54%, sports injuries in 31%, and traffic accidents in 15% as primary mechanisms. Traffic accidents were statistically more frequent in the surgical group, likely because they cause more severe fractures requiring surgery. Additionally, older adolescents, who are at greater risk of traffic-related accidents, are more likely to have closed growth plates, necessitating surgical intervention similar to adults.

The average hospital stay for operatively treated patients in our study was 4 days, comparable to Pavone et al. [24], who reported 3.1 days.

Non-operatively treated patients were immobilized for an average of 22.3 days, whereas surgically treated patients required 34.3 days of immobilization. Hohloch et al. [27] reported average immobilization

duration of 3.69 weeks for conservatively treated patients, and 3.8 weeks for those treated with Kirschner wires. Similarly, Binder et al. [22] documented immobilization periods of 3 weeks in conservatively treated patients and 3.1 weeks in surgically treated patients. These findings indicate that surgical patients require longer immobilization periods, likely due to greater fracture severity, whereas milder fractures heal faster with conservative treatment.

Among the 15 patients who underwent internal fixation, 8 (53%) were treated with elastic nails, 6 (40%) with Kirschner wires, and 1 patient (7%) with a locking plate. Binder et al. [22] predominantly used Kirschner wires (87.5%), locking plates (7.5%), screws, and external fixators (2.5% each). While Kirschner wires showed favorable outcomes, other studies [28] also highlight with the effectiveness of elastic nails. This underscores the need for further comparative research to determine the optimal fixation method, considering patient-specific factors. A standardized treatment algorithm could aid surgeons in selecting the most appropriate technique.

Several limitations must be acknowledged. As a retrospective study, detailed longitudinal follow-up was not possible. Additionally, the small surgical cohort ($n = 25$) reduces the statistical power and reliability of our findings. The broad categorization of injury mechanisms was another limitation – future studies should subdivide injury types to better identify risk factors for proximal humerus fractures in children. Furthermore, our study did not assess long-term functional outcomes. A prospective study evaluating func-

tional recovery (e.g., Constant score at one year post-injury) would provide a more comprehensive understanding of treatment efficacy. These limitations underscore the need for cautious interpretation of the study results and highlight the importance of further research to address these gaps.

Conclusion

Proximal humerus fractures occur equally in both sexes, with the highest incidence in children age 7 to 12 years. While no significant differences in age or gender distribution were observed among surgically treated patients, older children were more likely to undergo surgery, likely due to growth plate closure and reduced bone remodeling capacity. Falls were the most common injury mechanism across all patients, whereas traffic accidents were significantly more frequent among surgically treated patients, reflecting the greater severity of these fractures.

Surgical patients also required longer immobilization, further indicating higher fracture severity. Approximately 10% of children required surgical intervention, with elastic nails and Kirschner wires providing effective treatment options.

To optimize management, fractures should be classified using the Neer-Horowitz system. Future research should focus on longitudinal studies assessing functional outcomes through standardized shoulder function tests, which would help refine treatment strategies and improve clinical decision-making for pediatric proximal humerus fractures.

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