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ORIGINAL ARTICLE

Age, fracture severity, injury mechanisms and concomitant injuries predict surgical intervention in pediatric proximal humerus fractures

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ABSTRACT

Objective: Proximal humerus fractures (PHFs) in children often heal well with conservative treatment due to the region's high remodeling potential. However, the decision to operate becomes more nuanced in older children or those with severe fracture displacement or high-energy trauma. This study aimed to identify factors associated with operative management of pediatric PHFs.

Materials and Methods: We retrospectively reviewed 41 pediatric patients (aged 6–16 years) with PHFs treated between 2014 and 2024. Patient demographics, Neer-Horowitz classification, injury mechanisms, and presence of concomitant injuries were analyzed. Injury mechanisms were categorized as low-energy or high-energy. Outcomes were assessed using the Pediatric/Adolescent Shoulder Survey (PASS) at final follow-up. Multivariate logistic regression was used to identify independent predictors of surgical treatment.

Results: Of the 41 patients, 19 (46.3%) underwent surgical fixation, while 22 (53.7%) were treated nonoperatively. Patients in the operative group were older (mean 13.2 vs. 10.7 years, $p < 0.001$) and more likely to have Neer-Horowitz Grade III or IV fractures (89.5% vs. 40.0%, $p < 0.001$). High-energy trauma (94.7% vs. 59.1%, $p = 0.003$) and concomitant injuries (52.6% vs. 27.3%, $p = 0.001$) were significantly more frequent in the surgical group. On multivariate analysis, independent predictors of surgery included older age (OR 1.49, $p = 0.018$), Grade III/IV fractures (OR 5.41, $p = 0.015$), high-energy trauma (OR 4.57, $p = 0.040$), and concomitant fractures (OR 5.13, $p = 0.042$). At final follow-up, there was no significant difference in PASS scores between groups (operative: 87.8, nonoperative: 88.9; $p = 0.68$).

Conclusion: Age, fracture severity, high-energy trauma, and concomitant injuries are significant predictors of surgical intervention in pediatric PHFs. However, both surgical and nonoperative treatments yielded excellent functional outcomes, highlighting the importance of individualized treatment strategy.

Keywords: pediatric proximal humerus fracture, surgical indications, Neer-Horowitz classification, high-energy trauma, functional outcomes

INTRODUCTION

Pediatric proximal humerus fractures are relatively uncommon, accounting for approximately 2–5% of all pediatric fractures [1-4]. The proximal humeral physis contributes nearly 80% of humeral growth, giving these fractures excellent remodeling capacity, especially in younger children [5]. As a result, minimally displaced fractures in younger patients are typically managed nonoperatively with excellent outcomes [2]. However, treatment decisions become more complex in older children, adolescents, and cases with substantial displacement or associated injuries [4,5].

There is ongoing debate regarding the appropriate indications for surgical treatment in this population [1,6]. Several classification systems have been proposed to guide treatment, with the Neer-Horowitz classification being one of the most widely used. While higher grades in this system are generally associated with a greater likelihood of operative intervention, clinical decisions often rely on a combination of factors; including patient age, fracture displacement, injury mechanism, and the presence of concomitant injuries. Despite this, few studies have comprehensively evaluated the interplay of these factors in predicting surgical management [7].

Moreover, children presenting with polytrauma or high-energy mechanisms may undergo surgery for other injuries, during which the proximal humerus fracture is addressed as part of the overall treatment strategy. This raises important questions about whether surgical management is always driven by the characteristics of the humerus fracture itself or whether trauma severity plays a significant role. Understanding the clinical, radiographic, and injury-related factors that influence treatment decisions is essential for developing consistent guidelines and avoiding unnecessary surgery in children who are expected to achieve good outcomes with conservative care [1,2,4,8].

The aim of this study was to evaluate the association of age, Neer-Horowitz classification, injury mechanism, and presence of associated injuries with operative management in pediatric PHF. We hypothesized that older age, higher fracture grades, high-energy trauma, and concomitant injuries would be significantly associated with surgical intervention.

MATERIALS AND METHODS

Study design and patient selection

Ethical approval for this study was obtained from the Hacettepe University Faculty of Medicine Local Ethics Committee (Protocol no. SBA 25-618). This retrospective study included pediatric patients with PHF who were treated at a tertiary referral center between January 2014 and December 2024. Eligible patients were identified through institutional databases using diagnostic codes and confirmed via radiographic review. Inclusion criteria were radiographically confirmed PHF, age between 6 and 16 years at the time of injury, and a minimum clinical follow-up of 12 months. Patients with pathological fractures, skeletal dysplasia, or incomplete clinical or radiographic documentation were excluded.

Demographic and injury-related variables were collected including age, sex, side of injury, trauma mechanism, presence of concomitant injuries, and fracture classification. Injury mechanisms were categorized based on clinical documentation and patient history. Low-energy trauma included ground-level falls during routine daily activity. High-energy trauma included high falls (e.g., from stairs, playgrounds, or rooftops) and motor vehicle accidents, both in-vehicle and out-of-vehicle traffic accidents. For statistical analysis, injury mechanisms were grouped into two categories, low-energy and high-energy trauma, to evaluate their association with the likelihood of surgical intervention. Associated injuries were defined as any concomitant musculoskeletal, neurological, or visceral injury diagnosed at presentation. Fracture severity was graded using the Neer-Horowitz classification, based on radiographic displacement.

Treatment approach

Patients were managed either conservatively or operatively based on fracture characteristics, patient age, and overall clinical condition. Conservative treatment was preferred for younger patients, minimally displaced fractures and patients whose condition was not suitable for surgery. It consisted of immobilization with a sling or shoulder orthosis, followed by gradual return to activity with physical therapy as needed (Figure 1). Operative treatment was preferred for older patients, displaced and angulated fractures, open injuries, patients with neurovascular compromise and polytrauma patients. It was performed under general anesthesia and involved closed or open reduction and percutaneous fixation with K-wires (Figure 2). Surgery was also considered if the patient had a concomitant fracture that required surgical fixation.

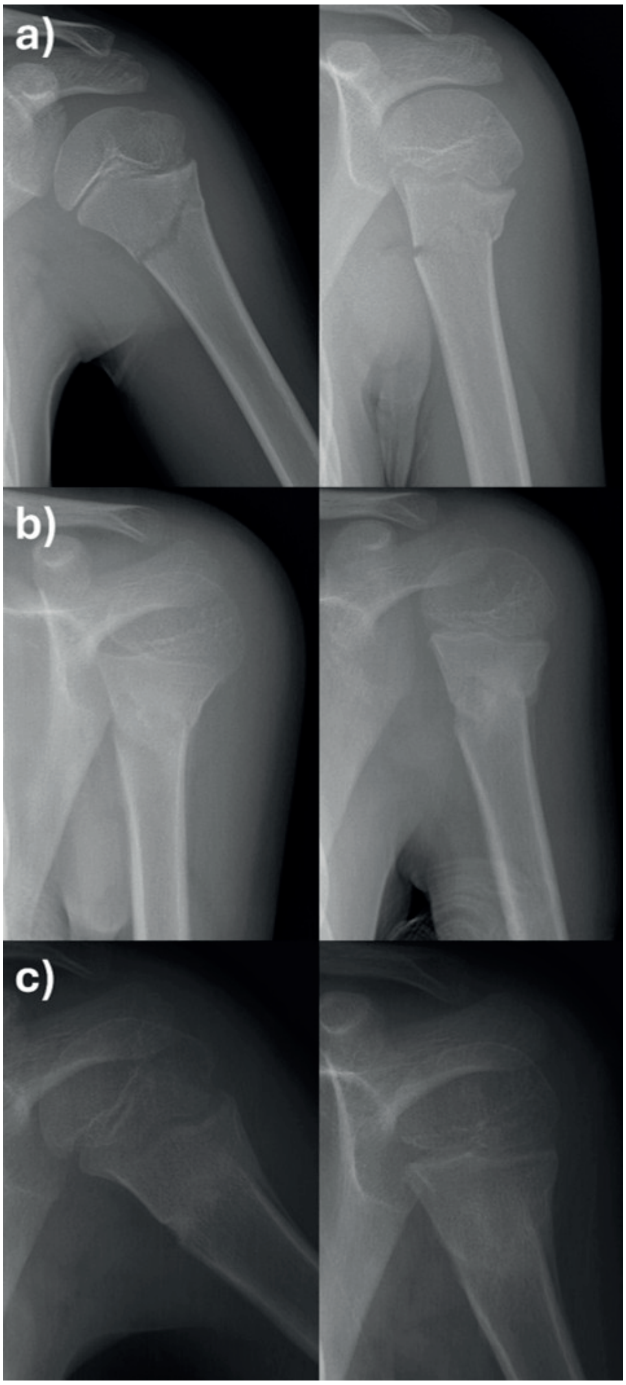

Figure 1. Radiographs of a 7-year-old. Left proximal humerus fracture after falling while playing

(a) Initial anteroposterior and lateral radiographs at the emergency department showing a minimally displaced proximal humerus fracture. The patient was treated conservatively with a Velpeau bandage.

(b) Follow-up radiographs at 3 weeks demonstrating early callus formation.

(c) Follow-up radiographs at 6 weeks showing abundant callus formation with remodeling.

Outcome assessment

Radiographic follow-up was performed at 2-week intervals until 6 weeks post-injury. In operatively treated patients, K-wires were removed at the 6th week, following confirmation of radiographic union. After this period, monthly radiographs were obtained until complete healing was confirmed. Clinical evaluation included range of motion and physical examination at each follow-up visit. Functional outcomes were assessed using the Pediatric/Adolescent Shoulder Survey (PASS) at the final follow-up visits [9].

Statistical analysis

Descriptive statistics were used to summarize the study population. Categorical variables were compared using chi-square or Fisher's exact tests, and continuous variables were analyzed using independent samples t-tests or Mann–Whitney U tests, depending on data distribution. Multivariable logistic regression analysis was performed to evaluate the association between operative management and variables including age, sex, fracture classification, injury mechanism, and presence of associated injuries. A p-value of <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY).

RESULTS

A total of 41 pediatric patients with PHF were included in the study. The mean age at injury was 11.5 ± 2.6 years (range, 6–16 years), and 25 patients (61.0%) were male. The dominant side was affected in 22 patients (53.7%). The mean duration of clinical follow-up was 26.7 ± 13.2 months (range, 12–60 months). Injury mechanisms were categorized as high-energy trauma in 31 patients (75.6%), which included motor vehicle accidents both out-of-vehicle (n = 16) and in-vehicle (n = 9) as well as high falls (n = 6). Low-energy falls were observed in 10 patients (24.3%) (Table 1). Concomitant injuries were present in 16 patients (39.0%), most commonly involving the tibia (n = 10), forearm (n = 4), or femur (n = 2) (Table 2). Nine of these patients underwent additional surgical procedures in the same session as proximal humerus fixation.

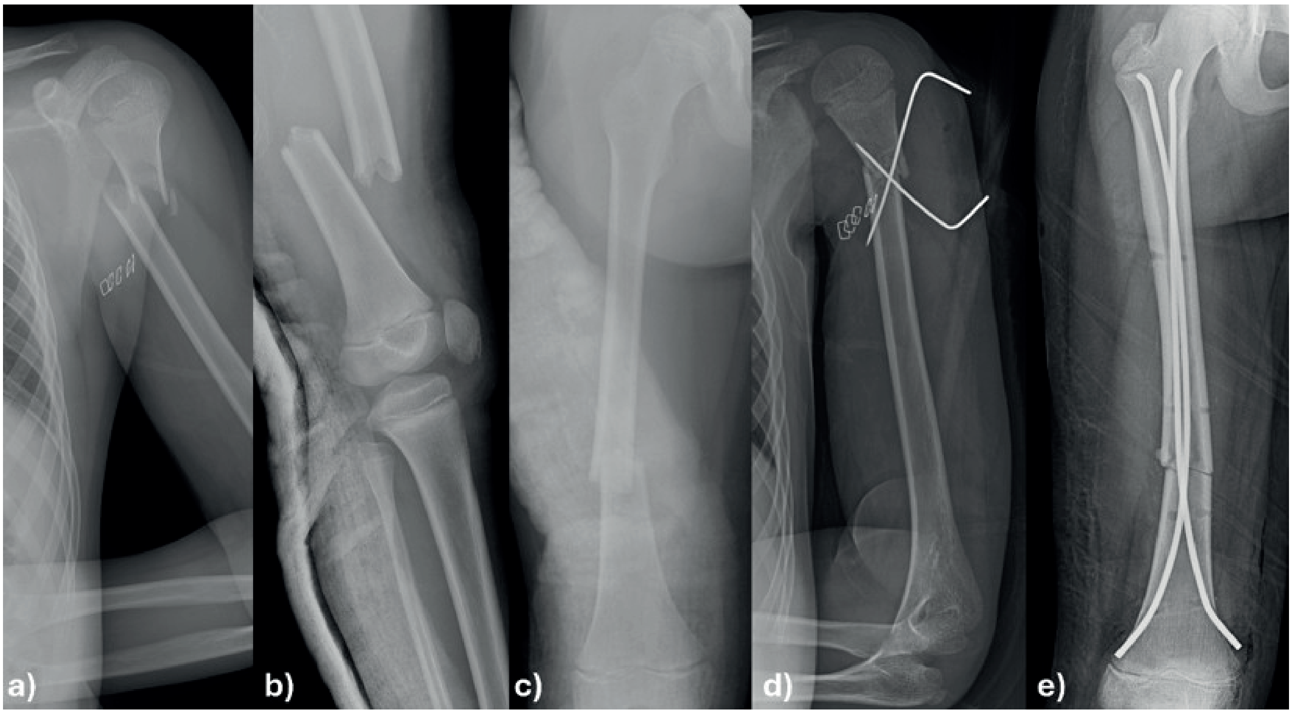

Figure 2. Radiographs of a 12-year-old male polytrauma patient following a traffic accident, referred intubated from a level 1 hospital

(a) Initial right shoulder radiograph showing displaced proximal humerus fracture.

(b, c) Initial right lower extremity radiographs demonstrating displaced distal femoral fracture.

(d) Postoperative right shoulder radiograph after closed reduction and percutaneous fixation with crossed K-wires.

(e) Postoperative right femur radiograph after closed reduction and stabilization with titanium elastic nails.

Table 1. Patient demographics and Injury characteristics

Variable	Operative (n=19)	Nonoperative (n=22)	Total (n=41)	p-value
Age (years), mean ± SD	13.2 ± 1.6	10.7 ± 2.6	11.5 ± 2.6	**<0.001**
Sex (male), n (%)	12 (63.2%)	13 (59.1%)	25 (61.0%)	0.79
Dominant side affected, n (%)	11 (57.9%)	11 (50.0%)	22 (53.7%)	0.62
Concomitant injuries, n (%)	10 (52.6%)	6 (27.3%)	16 (39.0%)	**0.001**
High-energy trauma, n (%)	18 (94.7%)	13 (59.1%)	31 (75.6%)	**0.003**

According to the Neer-Horowitz classification, 5 patients (12.2%) had Grade I fractures, 10 (24.4%) had Grade II, 11 (26.8%) had Grade III, and 15 (36.6%) had Grade IV fractures. Operative treatment was performed in 19 patients (46.3%), while 22 patients (53.7%) were managed nonoperatively (Table 3).

The mean age was 12.4 ± 3.33 among patients with Grade IV fractures (n=15), and 7 of them were male. Nine of them had concomitant fractures, and 11 of them sustained high-energy traumas. Patients whose condition was not suitable for surgery, younger patients' fractures with acceptable alignment after closed reduction and low-energy fractures with less soft tissue damage were treated conservatively.

Among surgically treated patients, 17 (89.5%) had Grade III or IV fractures, while only 2 (10.5%) had Grade I or II fractures. Seven patients underwent humerus fixation during surgery for other concomitant fractures.

Clinical outcomes

At final follow-up, the mean PASS score was 88.4 ± 9.1 in the entire cohort. The operative group had a mean PASS score of 87.8 ± 9.5, while the nonoperative group scored 88.9 ± 8.8, with no statistically significant difference between groups ($p = 0.68$). All patients achieved fracture union, and there were no reports of growth disturbances, osteonecrosis, or major complications.

Table 2. Associated fractures

Concomitant Fracture Type	Operative (n)	Nonoperative (n)	Total (n)
Tibia	8	2	10
Forearm	2	2	4
Femur	2	0	2

Table 3. Fracture Severity by Neer-Horowitz Classification

Neer-Horowitz Grade	Operative (n=19)	Nonoperative (n=22)	Total (n=41)	p-value
Grade I	0 (0%)	5 (22.7%)	5 (12.2%)	**<0.001**
Grade II	2 (10.5%)	8 (36.4%)	10 (24.4%)	
Grade III	6 (31.6%)	5 (22.7%)	11 (26.8%)	
Grade IV	11 (57.9%)	4 (18.2%)	15 (36.6%)	

Predictors of surgical intervention

Older age was significantly associated with surgical intervention, with operatively treated patients having a mean age of 13.2 years compared to 10.7 years in the nonoperative group ($p < 0.001$). Higher Neer-Horowitz fracture grades were also significantly associated with surgery, as 92.3% of patients in the operative group had Grade III or IV fractures, compared to 40.0% in the nonoperative group ($p < 0.001$). High-energy trauma mechanisms were more common in the surgical group (69.2%) than in the nonoperative group (25.7%), demonstrating a significant association ($p = 0.003$). Furthermore, the presence of concomitant fractures significantly increased the likelihood of operative management, occurring in 53.8% of surgically treated patients compared to 11.4% of nonoperative cases ($p = 0.001$). Multivariate logistic regression confirmed that older age (OR 1.49; 95% CI 1.07–2.07; $p = 0.018$), higher Neer-Horowitz grade (OR 5.41; 95% CI 1.38–21.1; $p = 0.015$), high-energy mechanism (OR 4.57; 95% CI 1.07–19.4; $p = 0.040$), and concomitant fractures (OR 5.13; 95% CI 1.06–24.9; $p = 0.042$) were all independently associated with operative treatment (Table 4).

DISCUSSION

This study identified age, fracture severity, high-energy trauma, and concomitant injuries as significant predictors of surgical intervention in pediatric PHFs. Although nearly half the patients underwent operative management, functional outcomes were excellent across both groups, demonstrating the high remodeling potential and favorable prognosis of these injuries in skeletally immature individuals.

Age has long been established as a critical factor in treatment decisions for PHFs due to the remodeling capacity of the proximal humeral physis, which contributes approximately 80% of the humerus's longitudinal growth [2,5]. Younger children typically recover well even from moderately displaced fractures, while older children and adolescents are more likely to require surgical correction due to decreased remodeling potential [5]. In our cohort, this age-dependent trend was clearly evident and supports the threshold proposed by Lefèvre et al., who suggested considering surgery in children older than 11 years with significant displacement [5].

Table 4. Multivariate logistic regression analysis

Variable	Odds Ratio (OR)	95% Confidence Interval	p-value
Age (per year increase)	1.49	1.07 – 2.07	**0.018**
Neer-Horowitz Grade III/IV	5.41	1.38 – 21.1	**0.015**
High-energy trauma	4.57	1.07 – 19.4	**0.040**
Concomitant fracture	5.13	1.06 – 24.9	**0.042**

Fracture severity also played a major role, with Grade III–IV fractures significantly associated with surgical treatment. This finding is consistent with prior studies demonstrating that more displaced fractures are less likely to remodel acceptably and therefore carry a higher likelihood of operative management [1,6,7]. Our results align with Karagöz et al. who also reported higher surgical rates in patients with Neer-Horowitz Grades III and IV [7]. While conservative management is the standard approach for Grade I-II fractures, two patients with Grade 2 fractures underwent surgery. These decisions were influenced by concomitant injuries requiring surgical intervention, persistent severe pain, poor patient adherence to conservative treatment plans, and unsuccessful closed reduction attempts. While these fractures show good response to conservative approaches, surgical approaches may give better results in selected cases.

In polytrauma cases, the management strategy differed from other patients. The treatment decision was not only influenced by fracture characteristics but also by the need for fixation of other fractures and the overall clinical condition of the patient. Internal fixation of the humerus was performed in the same session if the patient had any fractures that needed surgery. Patients who were in poor systemic condition or had contraindications for surgery were managed conservatively. In our study, seven patients underwent humerus fixation during the surgical session for concomitant fractures, and four patients couldn't be operated on because of their overall condition. These patients were followed at the intensive care unit.

An important finding of our study is the identification of injury mechanism as an independent predictor for the decision to perform surgery. High-energy trauma, such as motor vehicle accidents and high falls, was more prevalent in the operative group and remained a significant factor even after adjusting for age and fracture type. While this association is often acknowledged clinically, it has not been consistently quantified in previous literature. Our findings extend those of Cruz et al., who observed increased surgical intervention in polytrauma cases, suggesting that global injury severity, not just fracture characteristics, can influence treatment decisions [8].

Concomitant injuries were also an important factor influencing the decision of surgical management. In many cases, PHFs were surgically treated during operative treatment of other fractures. This pattern has been noted in other studies, including those by Song et al. and Fiandeiro et al., who emphasized the need to consider broader trauma patterns in pediatric upper extremity injuries [4,9]. Such combined procedures may reflect logistical efficiency and patient safety considerations in polytrauma care, but they also complicate the evaluation of fracture-specific treatment outcomes.

Importantly, our study supports that both surgical and conservative treatment approaches can yield excellent functional recovery when appropriately selected. The lack of difference in PASS scores aligns with the meta-analysis by Song et al., which found no consistent functional advantage for surgery in pediatric PHFs when stratified by age and displacement [4]. This emphasizes the continued relevance of nonoperative care in younger children or those with less severe displacement, particularly in isolated injuries.

Several limitations must be acknowledged. The retrospective design introduces potential selection bias, particularly in surgical decision-making, which may be influenced by individual surgeon preference or institutional protocols. Although we used validated classification systems and functional scores, the assessment of PASS may not fully capture subtle strength or ROM differences. Finally, as a single-center study from a tertiary institution, our results may not generalize to all practice settings, especially those with different surgical thresholds or resource availability.

CONCLUSION

Our findings show that age, fracture severity, high-energy injury mechanism, and concomitant trauma are significant predictors of surgical intervention in pediatric PHFs. Nevertheless, functional outcomes were excellent across both groups, supporting the case-specific approach. These results support existing literature and highlight the importance of considering not only radiographic but also systemic and clinical factors when managing these injuries.

Author contribution

Study conception and design: MK, UCK, SI, OMK, GA and SK; data collection: MK, UCK, SI and OMK;

analysis and interpretation of results: MK, UCK, SI and OMK; draft manuscript preparation: MK, UCK, SI, OMK, GA and SK. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Hacettepe University Faculty of Medicine Local Ethics Committee (Protocol no. SBA 25-618/08.07.2025).

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Conflict of interest

The authors declare that there is no conflict of interest.

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