INTEGRATING CASE-BASED LEARNING IN MEDICAL CURRICULUM: A STUDY ON SUPRACONDYLAR HUMERAL FRACTURES IN PEDIATRIC PATIENTS

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ABSTRACT

To evaluate the clinical and functional outcomes of children with supracondylar humeral fractures who underwent delayed open reduction and percutaneous pinning (ORPP) more than two weeks post-injury. A retrospective study was conducted at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma. The study included 56 children aged 6 months to 12 years with Gartland type II and III supracondylar humeral fractures treated with ORPP. Data were collected on demographic characteristics, fracture classification, time to surgery, radiological findings, and functional outcomes. Disabilities of the Arm, Shoulder, and Hand (DASH) scores were used to assess recovery at 3 months postoperatively, and postoperative complications were documented. The mean time from injury to surgical intervention was 16 days (range: 14–18 days). All fractures achieved radiological union, with 75% of cases uniting by 8 weeks and the remainder by 12 weeks. At 3 months postoperatively, 80% of patients had DASH scores indicating good to excellent functional recovery, with minimal restrictions in activities such as playing, writing, and dressing. The remaining

20% experienced moderate functional limitations, primarily due to soft-tissue stiffness and inconsistent adherence to physiotherapy. Radiographic evaluations confirmed restored alignment and normal carrying angles in all cases, with no significant differences in functional recovery between Gartland type II and III fractures (p> 0.05). Postoperative complications were rare, with only two cases of pin-site infection, both managed conservatively without long-term sequelae. No major complications, including neurovascular injuries, malunion, or growth disturbances, were observed. Adherence to structured physiotherapy protocols significantly improved range of motion and DASH scores, emphasizing the importance of rehabilitation in optimizing outcomes. Delayed open reduction and percutaneous pinning for pediatric supracondylar humeral fractures provides favorable clinical and radiological outcomes, even when performed beyond the conventional two-week window. This study highlights the viability of ORPP as an effective intervention in resource-constrained settings, underscoring the critical role of comprehensive postoperative care and physiotherapy in ensuring optimal recovery.

KEYWORDS
Supracondylar fractures humerus, Gatland Classification, open reduction, and percutaneous pinning (ORPP)

INTRODUCTION

Supracondylar humeral fractures are the most common type of elbow fractures in children, accounting for approximately 60% of all elbow fractures and 15% of pediatric fractures overall. These injuries are often the result of falls onto an outstretched hand, where hyperextension at the elbow leads to posterior displacement of the distal humeral fragment. This mechanism predominantly causes extension-type supracondylar fractures, which represent the majority of pediatric cases. The incidence of these fractures' peaks between the ages of 5 and 7 years, coinciding with the high activity levels of children in this age group and their increased vulnerability to accidental falls. The Gartland classification system is widely employed to categorize supracondylar humeral fractures, providing valuable guidance for treatment decisions. Type I fractures are non-displaced and generally managed conservatively with immobilization. Type II fractures involve angulation or slight displacement but can often be treated with closed reduction and percutaneous pinning (CRPP), which remains the gold standard for displaced fractures due to its minimally invasive approach and stable fixation. Type III fractures, characterized by more severe displacement and possible neurovascular compromise, frequently require open reduction and percutaneous pinning (ORPP), particularly when closed reduction proves unsuccessful.

While early surgical intervention is optimal, delayed presentations of pediatric supracondylar fractures remain a significant challenge, particularly in low- and middle-income countries (LMICs). Delays in seeking medical care are influenced by factors such as limited access to healthcare, cultural practices (e.g., bonesetter interventions), and misconceptions about fracture healing. Studies such as those by Gage et al. (2003) and Lee et al. (2011) have highlighted the impact of delayed presentation on outcomes, including callus formation, joint stiffness, and increased difficulty in achieving anatomical reduction. Furthermore, delayed surgical intervention is associated with a higher risk of complications, including malunion, growth disturbances, and neurovascular injuries. Despite these challenges, ORPP has proven to be an effective treatment option for cases with delayed presentations, as it allows direct visualization and precise alignment of the fracture. Research by Mehlman et al. (2001) and Boyer et al. (2010) has demonstrated that ORPP can achieve favorable outcomes even in cases where surgery is delayed beyond the ideal window, particularly when performed by skilled surgeons. These studies suggest that the pediatric skeleton has a remarkable capacity for healing, even in less-than-ideal circumstances, making ORPP a viable option for managing late-presenting fractures.

The role of postoperative care, particularly physiotherapy, is also crucial in ensuring favorable functional outcomes. Studies by Abzug et al. (2018) and Berard et al. (2015) have shown that structured rehabilitation programs improve range of motion and reduce the risk of joint stiffness, which is a common complication following supracondylar fracture surgery. Furthermore, the Disabilities of the Arm, Shoulder, and Hand (DASH) score has been widely used to assess functional recovery in pediatric populations, providing a reliable measure of arm function following fracture treatment.

This study aims to assess the clinical and functional outcomes of children with Gartland type II and III supracondylar fractures treated with ORPP after a delay of more than two weeks from the time of injury. By focusing on delayed cases, this research seeks to address a critical gap in the literature and evaluate the efficacy of ORPP under suboptimal conditions. Additionally, the findings underscore the need for medical education strategies, such as case-based learning (CBL), to prepare healthcare providers to manage complex trauma cases effectively and improve treatment outcomes, particularly in resource-constrained settings.

LITERATURE REVIEW

Supracondylar humeral fractures are among the most common pediatric injuries, accounting for 60–70% of all elbow fractures in children under 12 years of age. Early surgical intervention within 72 hours of injury is widely considered the standard for

achieving optimal outcomes and minimizing complications such as malunion, neurovascular compromise, and joint stiffness. However, delayed management, particularly beyond two weeks post-injury, remains a topic of debate, primarily due to the increased technical difficulty, risk of stiffness, and potential for suboptimal functional recovery.

The Gartland classification system provides a widely accepted framework for categorizing the severity of supracondylar fractures, with type II and III injuries often necessitating surgical intervention due to significant displacement or instability. Studies comparing early versus delayed surgical treatment have shown mixed results. While early intervention is associated with fewer complications and faster recovery, recent research indicates that delayed open reduction and percutaneous pinning (ORPP) can also yield favorable outcomes, particularly when performed with careful preoperative planning and appropriate postoperative care.

Functional recovery in pediatric elbow fractures is commonly assessed using standardized tools like the Disabilities of the Arm, Shoulder, and Hand (DASH) score. Evidence suggests that even in cases of delayed surgery, most children achieve satisfactory functional recovery, provided that anatomical alignment and stable fixation are achieved. Radiological union typically occurs within 6 to 12 weeks, depending on the severity of the injury and the timing of intervention. Despite growing evidence supporting delayed surgical intervention, gaps remain in understanding its long-term outcomes, especially in resource-limited settings where timely surgery is often unfeasible. Additionally, the impact of delayed surgery on activities of daily living, such as playing, writing, and dressing, warrants further exploration to guide clinical practice.

RESEARCH OBJECTIVE

1. To assess the clinical and functional outcomes of delayed open reduction and percutaneous pinning (ORPP) performed more than two weeks post-injury in children with Gartland type II and III supracondylar humeral fractures, focusing on radiological union rates, functional recovery using DASH scores, and postoperative complications.

RESEARCH METHODOLOGY

Study Design and Setting

This retrospective cohort study was conducted at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma (SMBBIT) in Karachi, Pakistan, between February 2018 and January 2023. The study was approved by the institutional review board (IRB), and patient consent was waived due to the retrospective nature of the study. The

medical records of children aged 6 months to 12 years who were treated for Gartland type II and III supracondylar humeral fractures with open reduction and percutaneous pinning (ORPP) after a delay of more than two weeks were reviewed.

Inclusion and Exclusion Criteria

We included children with Gartland type II and III supracondylar humeral fractures, both extension-type and flexion-type fractures, who underwent ORPP after a delay of at least two weeks from the time of injury. The inclusion criteria were:

1. Children aged 6 months to 12 years with Gartland type II or III supracondylar fractures.
2. Fractures treated with ORPP after more than two weeks from the time of injury.
3. Availability of clinical records and follow-up data for at least 3 months postoperatively.

Exclusion criteria included

1. Children with open fractures or those treated by bonesetters.
2. Patients with associated vascular injuries or those requiring vascular surgical intervention.
3. Children with non-supracondylar humeral fractures or fractures of other elbow regions (e.g., medial or lateral epicondyle fractures).
4. Cases with incomplete clinical or radiographic data or those lost to follow-up before the 3-month postoperative mark.

Surgical Technique

All surgeries were performed under general anesthesia by experienced orthopedic surgeons, following a standardized protocol. A posterior approach was used for open reduction, with careful dissection to avoid damage to the neurovascular structures. Once the fracture was reduced, fixation was achieved using two or three crossed Kirschner wires (K-wires) under fluoroscopic guidance to ensure proper alignment and stabilization of the fracture. The K-wires were inserted from lateral to medial, crossing at the fracture site for optimal fixation. Postoperatively, the affected limb was immobilized in a splint for 1-2 weeks to allow for initial healing. Stitches were removed at two weeks postoperatively, and K-wires were removed at three weeks, depending on radiological evidence of sufficient fracture healing. Follow-up visits were scheduled at 4, 8, and 12 weeks to monitor radiological union and assess for any complications.

Outcome Measures

The primary outcomes of interest were clinical and radiological.

- **Functional Outcomes**: Functional outcomes were assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) scoring system, which measures upper-limb disability in activities of daily living. The DASH score was recorded at 2 and 3 months postoperatively. A lower score indicates better functional recovery.

- **Radiological Union**: Radiological assessment of fracture union was performed at 4, 8, and 12 weeks postoperatively through serial anteroposterior (AP) and lateral X-rays of the elbow. Union was defined as the presence of bridging callus and the absence of fracture line at the fracture site.

- **Complications**: Any complications, including pin-site infections, malunion, neurovascular injury, or growth disturbances, were recorded during follow-up visits. Pin-site infections were managed conservatively with local wound care, and other complications were treated according to standard protocols.

Data Analysis

Statistical analysis was performed using SPSS version 20. Descriptive statistics were used to summarize the demographic data, fracture characteristics, and clinical outcomes. Continuous variables were expressed as means ± standard deviations, and categorical variables were presented as frequencies and percentages. The significance of differences between groups (e.g., between Gartland type II and type III fractures) was determined using appropriate statistical tests, such as the t-test or chi-square test. A p-value of less than 0.05 was considered statistically significant.

DATA ANALYSIS AND RESULTS

A total of 56 children met the inclusion criteria, with a mean age of 7.8 ± 3.1 years (range: 3–13 years). Among these, 62% (35 patients) presented with Gartland type III fractures, while the remaining 38% (21 patients) had Gartland type II fractures. The mean time from injury to surgical intervention was 16 days (range: 14–18 days), exceeding the traditionally recommended two-week window for optimal outcomes. Despite this delay, all patients achieved radiological union within 12 weeks postoperatively, with 75% (42 patients) demonstrating union by 8 weeks. This consistency in bone healing reinforces the resilience of pediatric bone physiology, even under suboptimal timing conditions.

At the 3-month follow-up, functional recovery was assessed using Disabilities of the Arm, Shoulder, and Hand (DASH) scores. A significant proportion, 80% (45 patients), attained scores indicative of good to excellent recovery. These patients reported minimal or no restrictions in daily activities such as playing, writing, and dressing.

Among the remaining 20% (11 patients), moderate functional limitations were noted. Contributing factors included soft-tissue stiffness, suboptimal compliance with postoperative physiotherapy, and, in three cases, mild residual pain during movement. Importantly, no cases of severe disability were observed.

Postoperative complications were minimal. Only two cases (3.6%) of pin-site infection were recorded, both of which resolved with conservative management involving oral antibiotics and meticulous local wound care. No instances of deep infection, malunion, neurovascular compromise, or growth disturbances were identified throughout the follow-up period. These findings emphasize the safety and reliability of open reduction and percutaneous pinning (ORPP) as a treatment strategy. Radiographic assessments showed excellent restoration of anatomical alignment in both anteroposterior and lateral planes. The mean Baumann angle and carrying angle fell within normal age-appropriate ranges, with no significant differences between Gartland type II and type III fractures ($p > 0.05$). Functional recovery was comparable across the two groups, highlighting the efficacy of ORPP irrespective of fracture severity.

A subgroup analysis revealed that adherence to physiotherapy protocols significantly influenced recovery trajectories. Patients who participated in structured physiotherapy sessions exhibited a more rapid improvement in range of motion and DASH scores by the 6-week mark compared to their counterparts who did not adhere to rehabilitation protocols ($p < 0.01$). For these patients, the supervised exercises likely mitigated joint stiffness and muscle atrophy, underscoring the critical role of postoperative care in pediatric trauma recovery.

These findings highlight that while delayed surgical intervention is often unavoidable due to logistical and systemic constraints, it does not necessarily compromise clinical or functional outcomes in pediatric supracondylar humeral fractures. Comprehensive postoperative care, including structured physiotherapy, emerges as a pivotal factor in optimizing recovery and minimizing complications in this population.

DISCUSSION

This study demonstrates the viability of open reduction and percutaneous pinning (ORPP) in pediatric patients presenting with delayed supracondylar humeral fractures. The successful outcomes in terms of radiological union and functional recovery align with existing literature, which supports ORPP in complex cases where delayed intervention is necessary. Supracondylar fractures in children are typically managed using closed reduction and percutaneous pinning (CRPP); however, when fractures present after a delay or when closed methods are not feasible, ORPP has proven to be a suitable alternative.

The use of ORPP in delayed cases is notable, especially given the challenges that typically accompany late interventions, such as increased callus formation that complicates reduction. Studies by Vuillermin et al. (2018) emphasize the importance of timely intervention but acknowledge that delayed surgical management can still yield satisfactory outcomes under certain circumstances. Additionally, the technical challenges associated with delayed cases are highlighted by Rupp et al. (2019), who noted increased complexity in achieving optimal alignment and maintaining stability postoperatively. Further, our results are consistent with the findings of Saeed and Waseem (2022), who suggest that even with delayed surgery, proper reduction techniques and fixation methods can result in favorable functional outcomes. They emphasize the significance of post-operative care and physiotherapy to enhance recovery, especially in pediatric patients with active lifestyles. The limitations of our study, which include its retrospective nature and absence of a control group, suggest a need for future prospective research. Comparing early versus delayed ORPP outcomes could offer deeper insights into optimal timing and rehabilitation protocols. Enhanced protocols, as indicated by Terpstra et al. (2022), may further improve the long-term functionality and reduce complications. This study also underscores the importance of integrating case-based learning (CBL) within the medical curriculum to familiarize future clinicians with decision-making in complex trauma cases. CBL offers a platform for understanding the multifaceted nature of delayed interventions and equips medical students with practical insights that align with real-world scenarios.

This study demonstrated favorable outcomes for children who underwent ORPP for supracondylar humeral fractures beyond two weeks after the injury. Despite the delay in surgery, we achieved satisfactory radiological union and functional recovery in the majority of cases. The results support the viability of ORPP for managing delayed cases, even though delayed surgery is often associated with technical challenges, including increased difficulty in reduction due to callus formation. Our findings align with previous studies that suggest delayed treatment of supracondylar fractures can still lead to good outcomes with appropriate surgical intervention. Furthermore, the use of open reduction enabled direct visualization and manipulation of the fracture, allowing for better alignment and stability in cases where closed reduction was not possible.

A limitation of this study was its retrospective nature and the lack of a control group receiving early intervention. Future prospective studies comparing early versus delayed ORPP may provide more definitive guidance on the timing of surgery in pediatric supracondylar fractures. Additionally, we recommend further research into optimizing postoperative rehabilitation protocols to enhance functional recovery. Open reduction and percutaneous pinning (ORPP) have proven to be a reliable and effective

option for managing delayed supracondylar humeral fractures in children. Despite the challenges posed by delayed presentations, including potential complications related to soft tissue and bone healing, ORPP resulted in excellent radiological and functional outcomes. Most children in this study achieved union within 8 to 12 weeks, with minimal restrictions in daily activities, as indicated by the Disabilities of the Arm, Shoulder, and Hand (DASH) scores. Importantly, the incidence of major complications such as malunion, neurovascular injury, and infection was low, suggesting that ORPP can be performed safely even in cases where surgery is delayed beyond the ideal two-week window.

The positive outcomes observed in this study reinforce the notion that delayed surgical intervention, when managed appropriately, can still yield favorable results. The use of ORPP allows for accurate fracture alignment and stabilization, which is critical for achieving optimal recovery in pediatric patients. This approach should be considered a viable option in resource-constrained settings or situations where children present late for care, particularly in low- and middle-income countries (LMICs), where delays in seeking medical attention are common due to factors such as limited healthcare access, cultural practices, and misperceptions about fracture healing. Furthermore, this study highlights the importance of postoperative rehabilitation in optimizing functional recovery. Structured physiotherapy protocols significantly improved range of motion and contributed to better functional outcomes, emphasizing the need for a comprehensive care approach that includes not only timely surgical intervention but also effective rehabilitation strategies.

In conclusion, ORPP is a reliable and effective treatment for delayed pediatric supracondylar humeral fractures, providing excellent outcomes even when surgery is performed later than recommended. These findings support the use of ORPP in settings with delayed fracture presentations, offering a viable solution to managing these challenging cases. Future research should focus on refining treatment protocols for delayed fractures and assessing long-term functional outcomes to further guide clinical decision-making.

RECOMMENDATIONS

Since it’s a retrospective study, a prospective study can be done to compare the results and these patients enrolled in study are on regular follow-up a study can be made to compare the differences.

Similar study can be done in adult population to compare the advantage of clinical and functional outcomes with supracondylar humeral fractures who underwent delayed open reduction and percutaneous pinning (ORPP) more than two weeks post-injury.

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