Fracture Patterns and Peripheral Brachial Plexus Injury in Humerus Fractures: A Retrospective Study

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Abstract

Background Peripheral brachial plexus injuries, particularly Radial nerve palsy (RNP), are a common complication of humeral shaft fractures. Despite previous research, the specific fracture patterns associated with RNP remain unclear.

Objectives This study aims to assess the frequency and patterns of humeral shaft fractures, determine the incidence of peripheral brachial plexus injuries such as radial and ulnar nerve palsies, and investigate the association between specific fracture patterns and these nerve injuries. We also explored other factors influencing RNP development and identified potential risk factors or predictors.

Methods This retrospective cohort study analyzed 144 patients with humeral shaft fractures at King Saud Medical City from 2015 to 2022. Patient data, such as age, gender, and neurovascular status, were extracted and analyzed using SPSS. RNP was diagnosed clinically. Statistical analyses included chi-square and student *t*-tests, with a *p*-value of <0.05 for significance.

Results This study found a 37.5% incidence of RNP in humeral shaft fractures. Significant differences were observed in age ($p = 0.032$) and mechanism of injury ($p < 0.0001$), with most fractures due to road traffic accidents (72.22%) and closed (93.75%). Common fracture patterns were AO 12A (37.5%) and AO 12B (39.58%), with a higher prevalence of comminuted fractures (71 cases). Significant differences in fracture patterns ($p < 0.0001$) and anteromedial comminution ($p = 0.002$) were noted between patients with and without RNP. Interestingly, four cases of concomitant ulnar nerve palsy were observed in patients with radial nerve palsy. However, no significant differences were found in gender ($p = 0.343$), open fractures ($p = 0.214$), or associated fractures ($p = 0.106$).

Conclusion This study suggests that the severity of trauma, rather than specific fracture patterns, is a more significant factor in RNP development in humeral shaft fractures. Further research is needed to understand the underlying biomechanics.

Keywords
- humeral shaft fracture
- radial nerve palsy
- fracture pattern
- retrospective cohort
- trauma severity
- biomechanics

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Introduction

The radial nerve is one of the terminal branches that originated from the posterior cord of the brachial plexus. Its unique course in the arm predisposes it to a higher chance of injury. In the arm, it traverses the humerus from medial to lateral, around 20 cm from the medial epicondyle and 14 cm from the lateral epicondyle. After traversing the humerus, the nerve will enter the lateral intermuscular septum and travel posterolateral to the humerus and elbow joint.[1,2]

According to some studies, radial nerve palsy (RNP) estimates are around 8.5 to 11.8% in all humeral shaft fractures.[3–9] As expected, most of the RNP results from middle and distal shaft fracture of the humerus. It is hypothesized that spiral distal humerus fracture, known as Holstein-Lewis fracture, has the highest rate of RNP since the nerve lies in direct contact with the lateral cortex of the humerus. This is due to distal fragment lateral displacement, which can lead the radial nerve to be lacerated or entrapped between the bone fragments.[10] In a study done by Shao et al,[5] the authors suggested that the connection between Holstein–Lewis fractures and RNP may not be as significant as initially thought. Their systematic review indicates that the area of risk encompasses both the middle and distal parts of the shaft. This was also implied in a study by Ekholm et al,[11] where he found that Holstein–Lewis fracture and other simple fracture patterns, such as transverse and oblique, are equal in causing RNP.

Biomechanically, the fracture happens because of significant compression on one side of the cortex, which in turn will lead to tension in the other cortex. In pediatric supracondylar humerus fracture, the presence of RNP is associated with fracture pattern. Posteromedial displacement results in higher RNP.[12,13] This is attributed to the biomechanics of the fracture, whereas posteromedial displacement will put the lateral structures in tension. This is also seen with distal femur physeal fracture, where the tension side usually has entrapped soft tissue (periosteum) and the metaphyseal comminution on the compression side.[14]

Despite these insights, there remains a knowledge gap in our understanding of the specific fracture patterns in humeral shaft fractures predisposing to RNP. This study aims to examine the association between various fracture patterns in the humeral shaft and the occurrence of RNP, thus providing a clearer understanding of the mechanisms behind this complication.

Methods

Study Design

This is a retrospective cohort study conducted at King Saud Medical City (KSMC), which is a level I Trauma center located in the central region of Riyadh, Saudi Arabia. It is considered the largest Ministry of Health Community trauma center and destination for referral to secondary hospitals. We included all cases presented to our hospital from January 1, 2015, to June 2022, with the diagnosis of humerus shaft fractures after obtaining approval from the Institutional Review Board (IRB) of KSMC. The primary aim of the study is to assess the pattern of fracture and its association with RNP. The secondary aim of the study was to assess the association between the mechanism of injury and RNP and the association of other nerve palsy, such as ulnar and median nerves.

Patient Selection

The included sample consisted of cases that presented acutely with humeral diaphyseal fracture (AO/OTA 12 A, B, and C) above the age of 14 years old. Cases excluded were pathological fractures, metaphyseal fractures, or patients who were lost to follow-up. We found 144 cases that met our criteria.

Data Collection

The patient's files were accessed through the medical records department after approval from the IRB (reference number: H1RI-31-Aug23–02). Data such as age, gender, neurovascular status, specifically RNP, mechanism of injury, and presence of open or closed fracture were extracted. Picture archiving and communication system (PACS) was used to analyze the imaging of humerus shaft fractures. Humerus shaft fractures were classified based on AO/OTA classification. Fractures were stratified based on the location of the comminution into anteromedial, anterolateral, posteromedial, posterolateral, and no comminution (►**Figs. 1**–**4**). RNP was diagnosed clinically by neurological examinations. RNP was defined as

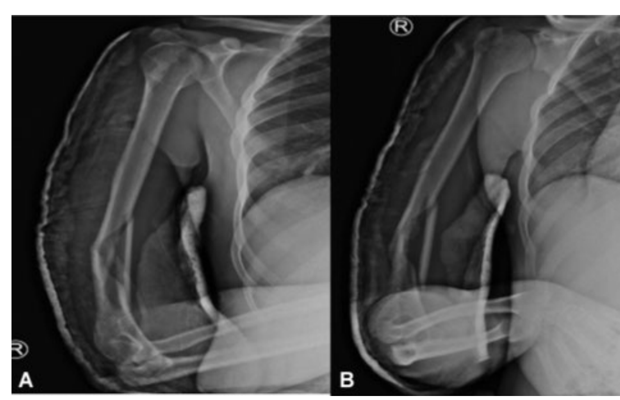

Fig. 1 (A) AP view of humerus showing anteromedial comminution. (B) Lateral view of the humerus with anteromedial comminution.

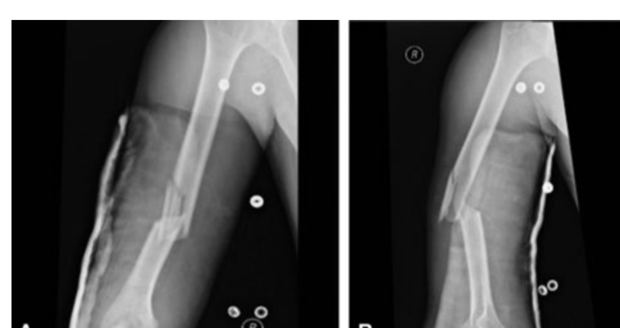

Fig. 2 (A) AP view of humerus showing anterolateral comminution. (B) Lateral view showing anterolateral comminution.

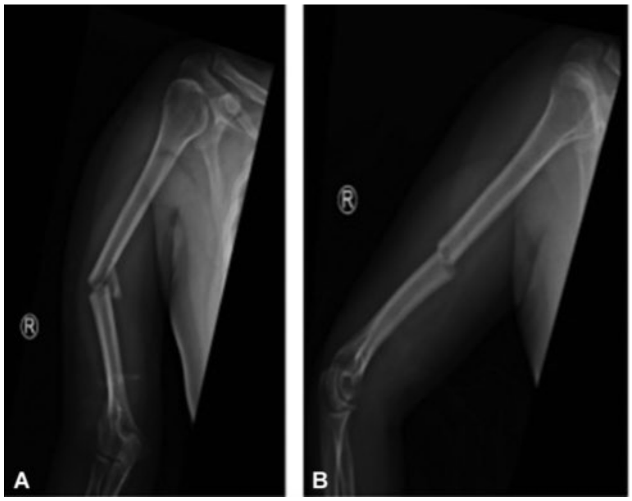

Fig. 3 (**A**) Shows AP view with posteromedial comminution. (**B**) Lateral view showing posteromedial comminution.

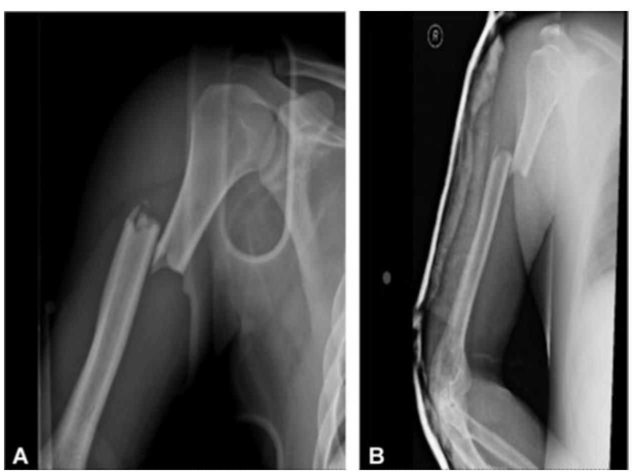

Fig. 4 (**A**) AP view showing posterolateral humerus comminution. (**B**) Lateral view showing posterolateral humerus comminution.

wrist and/or finger drop and or sensory deficit at the radial nerve territory. In addition, ulnar nerve palsy was identified as an inability to abduct the fingers and sensory deficit at the ulnar nerve territory.

Statistical Analysis

All cases were managed and followed at our hospital. Data were collected in an Excel sheet and analyzed using SPSS software (V.21.0, IBM Corp.). Patients were stratified into two groups, whether patients sustained RNP or not. Analysis of demographic data, including age, gender, and data such as the presence of open fracture, mechanism of injury, fracture pattern, and location of comminution, was done between the groups to see any differences that could affect the results when compared with the primary outcome. Categorical values were analyzed using the chi-square test. Numerical values were analyzed using a student *t*-test when two groups were compared. Data normality was assessed using the Shapiro–Wilk test. A *p*-value of less than 0.05 is considered statistically significant.

Results

The study included 144 cases: 18 (12.5%) females and 126 (87.5%) males. Age ranged from 16 to 78 years, with a mean age of 32.7 years. Out of 144 cases, there were 54 (37.5%) patients who sustained RNP, 4 of which had concomitant ulnar nerve palsy, and 90 (62.5%) patients who did not have RNP. Around 104 (72.22%) cases sustained a fracture due to RTA, 14 (9.72%) cases due to crush injury, and 26 (18.06%) cases due to fall. Of all fractures, 135 (93.75%) cases were closed fractures, and 9 (6.25%) cases were open. There were 54 (37.5%) cases of type AO 12A, 57 (39.58%) cases were AO 12B, and 33 (22.92%) cases were AO12C. Seventy-one (49.3%) cases were comminuted, and 73 (50.7%) cases were simple fracture cases (►**Table 1**).

When testing for RNP and the association between the variables. The group without palsy included 80 males (88.89%) and 10 females (11.11%), while the RNP group had 46 males (85.19%) and 8 females (14.81%), showing no significant gender difference ($p = 0.343$). The average age was 34.5 years (SD: 15.26) for the nonpalsy group and 29.89 years (SD: 10.17) for the palsy group ($p = 0.032$). In the nonpalsy group, there were 74 RTA cases (82.22%), no crush injuries (0%), and 17 falls (18.89%). The palsy group had 30 RTA cases (55.56%), 14 crush injuries (25.93%), and 9 falls (16.67%; $p < 0.0001$). Open fractures were less common, with

Table 1 Baseline characteristics for patients included in the study

Variable	Number of cases
Total cases	144
Females (%)	18 (12.5%)
Males (%)	126 (87.5%)
Radial nerve palsy (%)	54 (37.5%)
No radial nerve palsy (%)	90 (62.5%)
Mechanism of injury	
RTA (%)	104 (72.2%)
Crush (%)	14 (9.72%)
Fall (%)	26 (18.06%)
Closed fracture (%)	135 (93.75%)
Open fracture (%)	9 (6.25%)
AO/OTA classification	
AO 12A (%)	51 (35.41%)
AO 12B (%)	57 (36.11%)
AO 12C (%)	20 (13.88%)
AO 13A (%)	5 (3.47%)
AO 13B (%)	4 (2.77%)
AO 13C (%)	12 (8.33%)
Fracture pattern	
Comminuted (%)	71 (49.3%)
Noncomminuted (%)	73 (50.7%)

Table 2 Association of demographic, clinical, and radiographic factors with associated nerve palsy in patients with humerus fracture

Associated nerve palsy	Yes ($n=54$)	No ($n=90$)	p-Value
Male:Female (%)	46 (85.19%):8 (14.81%)	80 (88.89%):10 (11.11%)	0.343
Age	29.89 (SD: 10.17)	34.5 (SD: 15.26)	$p=0.032$
Mechanism of injury (%)	RTA: 30 (55.56%) Crush: 14 (25.93%) Fall: 9 (16.67%)	RTA: 74 (82.22%) Crush: 0 (0%) Fall: 17 (18.89%)	<0.0001
Open vs. closed fracture (%)	5 open (9.26%) 48 closed (90.74%)	4 open (4.44%) 87 closed (95.56%)	0.214
Fracture pattern (%)	AO 12A: 15 cases (27.77%) AO 12B: 16 cases (29.62%) AO 12C: 16 cases (29.62%) AO 13A: 3 cases (5.55%) AO 13B: 2 cases (3.70%) AO 13C: 2 cases (3.70%)	AO 12A: 36 cases (40%) AO 12B: 36 cases (40%) AO 12C: 4 cases (4.44%) AO 13A: 2 cases (2.22%) AO 13B: 2 cases (2.22%) AO 13C: 10 cases (11.11%)	<0.0001
Presence of comminution (%)	Comminution 31 (57.4%) No comminution 23 (42.6%)	Comminution 40 (44.44%) No comminution 50 (55.56%)	0.169

Table 3 Fracture characteristics

Associated nerve palsy	Yes ($n=54$)	No ($n=90$)	p-Value
Comminution	No = 22 Posteromedial = 4 Anteromedial = 21 Anterolateral = 5 Posterolateral = 2	No = 47 Posteromedial = 11 Anteromedial = 15 Anterolateral = 2 Posterolateral = 15	0.002
Associated fractures. No associated fractures	17 37	17 73	0.106

four cases (4.44%) in the nonpalsy group and five cases (9.26%) in the palsy group ($p=0.214$). The fracture pattern analysis for patients showed a statistically significant difference ($p<0.0001$). Comminution was observed in 40 patients (44.44%) without palsy and 31 (57.4%) with palsy ($p=0.169$; ►**Table 2**).

When analyzing we found that fracture comminution pattern was associated with RNP when we compared RNP cases to the cases who did not sustain nerve palsy ($p=0.002$). For instance, medial comminution was found to be significantly higher in RNP group (46.29%) compared to non-radial nerve palsy group (28.8%). In more details, patients without radial nerve palsy ($n=90$), 47 had no comminution (52.22%), 11 had posteromedial (12.22%), 15 anteromedial (16.67%), 2 anterolateral (2.22%), and 15 posterolateral (16.67%) comminutions. In the palsy group ($n=54$), 22 had no comminution (40.74%), 4 posteromedial (7.41%), 21 anteromedial (38.89%), 5 anterolateral (9.26%), and 2 posterolateral (3.70%) ($p=0.002$). Regarding fractures, 17 without palsy (18.89%) and 17 with palsy (31.48%) had associated fractures, whereas 73 without (81.11%) and 37 with palsy (68.52%) did not ($p=0.106$).

Discussion

In the study, significant findings included a higher incidence of RNP in younger patients, with an average age of 29.89 years in the palsy group compared with 34.5 years in the nonpalsy group. The cause of fractures varied significantly between groups, with road traffic accidents more prevalent in the nonpalsy group and crush injuries more common in the palsy group. Fracture patterns showed a notable difference; a more even distribution across AO types was observed in the palsy group, suggesting a strong association between AO 12C and the occurrence of RNP. Additionally, there was a significant variation in the location of comminution, particularly the higher incidence of anteromedial comminution in the palsy group. However, associated fractures did not show a significant difference between the groups.

Biomechanically, the butterfly fragment happens due to both compression and bending forces. If the bending forces start laterally, then the compression and comminution will be on the medial aspect of the humerus.[15] As a result, the fracture spike will happen on the lateral aspect of the humerus, which predisposes the radial nerve to injury. Our study found that medially sided comminution was associated with RNP in 46% (25 cases) and 28% (26 cases) of the nonpalsy group. This suggests that the location of the comminution is in fact related to RNP. Shao et al and Ekholm et al[5,10] found that the most common fracture patterns associated with RNP were simple fracture patterns such as transverse, oblique, and spiral fractures. Similarly, Khan et al conducted a retrospective study encompassing 80 patients with closed humeral shaft fractures; they found out the prevalence of RNP was around 8.75% (7/80), with most fractures spiral.[16] In our study, we did find differences regarding fracture comminution between RNP and non-palsy group and these findings suggest that medial-sided comminution could be risk factor for RNP.

In our study, we observed a strong correlation between RNP and high-energy injury mechanisms. Specifically, all cases of crush injuries (14 in total) in our study were linked with RNP. This observation aligns with findings from Kong et al,[9] who reported a 26.6% incidence of RNP associated with high-energy injuries. Furthermore, while the incidence of RNP in existing literature typically ranges from 8.5 to 11.8%, our study recorded a significantly higher prevalence of 37.5% (54/144 cases). This notable increase can likely be attributed to our study in a trauma center, where most cases involved high-energy injuries. Additionally, several studies regarding RNP found that the prevalence is significantly higher in population-sustained humeral shaft fractures due to high energy. For instance, Entezari et al found that 68% of all high-energy humeral shaft fracture cases sustained RNP.[17] Similarly, Lang et al reported that 52% of cases sustained RNP,[18] and Claessen et al reported 66 RNP cases out of 325 high-energy humeral shaft fractures.[19] This led both to conclude that the high energy mechanism of injury is the cause of RNP. As a result, we believe that certain fracture patterns are more prevalent in high-energy traumas rather than being directly linked to RNP. Hence, it is the intensity of the injury that increases the risk of RNP, rather than a specific pattern of fracture being a direct cause of RNP.

Interestingly, we found four cases that had concomitant ulnar nerve palsy with RNP. These cases were a result of high-energy trauma and were not associated with specific fracture patterns. Specifically, three occurred following RTA, while one was due to a crush injury. Two of the fractures were comminuted, and the remaining had simple fracture patterns. Pathak et al and Stahl et al[20,21] found similar cases of ulnar nerve palsy in humeral shaft fracture, and both cases were attributed to the mechanism of injury as the culprit in the nerve palsy.

While this study offers valuable insights into the relationship between humerus fractures and RNP, it is essential to acknowledge inherent methodological limitations. Additionally, the study's single-center nature and the sample size may restrict the generalizability of the findings to broader populations. Despite these limitations, our study adds to what we know about RNP in humeral fractures and suggests areas for more research.

Conclusion

In conclusion, this study sheds significant light on the complex relationship between RNP and humeral shaft fractures. Our findings suggest a complex interplay between the type of fracture, the mechanism of injury, and the occurrence of RNP. Our investigation reveals a higher RNP prevalence in high-energy trauma cases, such as crush injuries, challenging the widely held belief that specific fracture patterns, such as Holstein–Lewis fractures, predominantly cause RNP. The data points to the severity and nature of the trauma as more influential factors in RNP likelihood than the fracture pattern itself. These insights emphasize the importance of a deeper understanding of humeral shaft fracture biomechanics and their impact on nerve injury. The study's findings pave the way for further research in this domain, potentially leading to improved treatment strategies and better patient outcomes in humeral fractures.

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Conflict of Interest
None declared.

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