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Radial nerve palsy in humeral shaft fractures: Impact of surgical technique on outcomes

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Abstract

Background: Humeral shaft fractures, representing 3% of all fractures, have a bimodal distribution: low-energy falls in older adults and high-energy trauma in younger individuals. Radial nerve palsy (RNP) is a significant complication, with secondary RNP occurring in 10-20% of cases. This study examines the prevalence of secondary RNP following surgery for closed humeral shaft fractures and compares outcomes between radial nerve (RN) exploration and non-exploration.

Patients and Methods: This analytical cross-sectional study, conducted at Al-Yarmouk Teaching Hospital from April 2023 to April 2024, compared two surgical techniques for closed humeral shaft fractures: Open Reduction and Internal Fixation (ORIF) with and without RN exploration. It involved 38 adult patients, aged 18-60, divided into two groups: Group A (ORIF with RN exploration, n=22) and Group B (ORIF without RN exploration, n=16). Data collection included clinical assessments, radiological evaluations, and surgical observations. Statistical analysis was performed using SPSS, with ethical approval and informed consent obtained from all participants, adhering to national and international guidelines.

Results: In a study of 38 humeral shaft fractures treated with ORIF, 16% developed RNP. RN exploration during surgery did not significantly affect RNP rates (13.6% with exploration vs. 18.8% without, p=0.670). The average age of patients with RNP was 33.83 years, similar to those without RNP (36.44 years, p=0.608). The majority were male (71.1%), with Type A fractures being the most common (63.2%). RNP rates did not differ significantly by gender, fracture type, or level (p-values: 0.215, 0.540, and 0.736, respectively).

Conclusions: The study found a 16% incidence of RNP in patients with closed humeral shaft fractures treated with ORIF. No significant difference in RNP rates was observed between patients with or without RN exploration, and demographic factors or fracture characteristics did not affect RNP occurrence. Future research with larger samples and alternative techniques may be beneficial.

Keywords: Radial nerve palsy, humeral shaft fractures, surgical techniques, outcomes

Introduction

Humeral shaft fractures account for approximately 3% of all fractures [1]. These fractures often exhibit a bimodal distribution related to injury mechanisms: low-energy trauma, primarily from falls, affects older women, while high-energy trauma, commonly from road traffic accidents, predominantly impacts younger men [2]. The majority of humeral shaft fractures are simple fractures linked to low-energy injuries. A study by Ekholm *et al*. of 401 consecutive humeral shaft fractures found that 61% were classified as Arbeitsgemeinschaft fur Osteosynthesefragen (AO)/Orthopaedic Trauma Association (OTA) type A, or simple fractures, with 68% resulting from low-energy falls [3].

RNP is a notable complication associated with humeral shaft fractures, particularly those from high-energy trauma, and can also occur postoperatively following open reduction and internal fixation. The incidence of iatrogenic or secondary RNP ranges between 10-20% [4]. Kakazu *et al*. found that treatment of acute humeral shaft fractures with plates or nails could result in iatrogenic RNP rates of 6-24% [5]. Secondary RNP often arises from trauma during fracture manipulation, surgical instruments, and implants, or entrapment by fracture callus or scar tissue [6]. Management strategies for secondary RNP are debated, with some advocating for early surgical exploration due to frequent nerve entrapment, while others support conservative approaches [7].

The humeral shaft extends from the surgical neck to the epicondyles, with its proximal half being nearly cylindrical and the distal half tapering into a prismatic shape. The radial sulcus, which houses the RN and its nutrient foramen, traverses the posterior middle third of the humerus, the large surrounding muscles obscure direct palpation of the humerus, dividing the arm into anterior and posterior compartments by medial and lateral intramuscular septa [8].

The anterior compartment contains the biceps brachii, coracobrachialis, brachialis, brachial artery and vein, and the median, musculocutaneous, and ulnar nerves. The posterior compartment houses the triceps and the RN [9]. The RN's high injury rate is due to its proximity to the humeral periosteum. Notably, the RN is adjacent to the bone before exiting the spiral groove, approximately 10-15 cm proximal to the lateral epicondyle [9]. The "danger zone," where the nerve pierces the lateral intermuscular septum, is located around 12.3 cm ± 2.3 proximal to the olecranon fossa, making it particularly vulnerable due to minimal mobility [10].

The OTA and AO classification system for humeral shaft fractures, first published in 1996 and revised in 2007 and 2018, categorizes fractures into three main types [11]:

- **Type A:** Simple fractures
- **Type B:** Wedge fractures
- **Type C:** Multiffragmentary fractures

Each type is further subdivided based on fracture characteristics. Type A fractures are categorized into spiral (A1), oblique (A2), and transverse (A3). Type B fractures are divided into intact wedge (B2) and fragmentary wedge (B3). Type C fractures are split into intact segmental (C2) and fragmentary segmental (C3) with further subdivisions based on location [11].

Patients with humeral shaft fractures typically present with arm pain, deformity, and swelling. A comprehensive neurovascular examination is crucial since RN injuries occur in about 16% of these fractures. This evaluation includes assessing wrist and finger extension, thumb interphalangeal extension, and first web space sensation [12]. Additional assessments should document radial and ulnar pulses, skin integrity, and, if needed, Doppler pulse and compartment pressures [13]. For polytrauma patients, there's a need to consider associated injuries, such as open wounds, vascular injuries, brachial plexus injuries, and other fractures [14].

Initial imaging for humeral shaft fractures should include anteroposterior and lateral radiographs at 90º angles, including the shoulder and elbow joints. Traction radiographs can assist with comminuted or severely displaced fractures, and comparison with the contralateral side may be useful for preoperative planning [2].

Nonoperative management is generally indicated for acute, closed, isolated fractures in cooperative patients. Relative indications include type a fractures, proximal third long oblique fractures, and open fractures without neurovascular injury. Contraindications include significant vascular injury, pathologic fractures, and nonunited fractures [2]. Nonoperative techniques such as skeletal traction, Velpeau bandage, and functional bracing are employed, with functional bracing being the most prevalent in recent years [15].

Surgical intervention is indicated for cases where satisfactory reduction cannot be maintained, multiple injuries are present, or progressive nerve palsy occurs. Surgical options include plate osteosynthesis, minimally invasive plate osteosynthesis, and intramedullary nailing. Each method has specific indications, techniques, and potential complications, with a focus on achieving stable fixation while minimizing complications [16].

Aim of the Study

This study aims to investigate the prevalence of secondary RNP following surgical treatment of closed humeral shaft fractures using the anterolateral approach with plate and screw fixation. Additionally, it seeks to compare the outcomes between two surgical techniques: RN exploration versus non-exploration during the procedure.

Patients and methods

Study Design

This study employed an analytical cross-sectional design to investigate the outcomes of two different surgical techniques for the treatment of closed humeral shaft fractures at Al-Yarmouk Teaching Hospital. The cross-sectional design was chosen to allow for the collection of data from patients at a single point in time, facilitating the comparison between two surgical methods: ORIF with and without RN exploration. The design was particularly suited to the objective of evaluating the immediate and short-term surgical outcomes, including nerve function, fracture healing, and postoperative complications. The study period extended from April 2023 to April 2024.

Study Setting and Timing

The study was conducted in the Orthopedic Department of Al-Yarmouk Teaching Hospital, a major healthcare facility in Baghdad, Iraq. This hospital was selected due to its high volume of orthopedic cases, including humeral fractures, and its comprehensive surgical and postoperative care facilities. Data collection took place over one year, from April 2023 to April 2024. This extended timeframe allowed for the recruitment of a sufficient number of patients and the observation of early postoperative outcomes.

Sample Population, Size, and Technique

The study targeted adult patients presenting with acute, closed humeral shaft fractures. The inclusion criteria were adults aged 18-60 years with acute, closed humeral shaft fractures, excluding those with compound fractures, pathological fractures, non-union, primary RNP, and poor soft tissue conditions such as severe swelling or burns. A total of 38 patients met the inclusion criteria and were enrolled in the study. These patients were divided into two groups based on the surgical technique employed: Group A (n=22) underwent ORIF with RN exploration and Group B (n=16) underwent ORIF without RN exploration. Patients were selected consecutively as they presented to the hospital, ensuring a representative sample of the patient population.

Data Collection Tools

Data were collected through a combination of clinical assessments, radiological evaluations, and surgical observations. Upon arrival at the emergency department, each patient's general condition was assessed, including a detailed history, physical examination, and radiological evaluation using anteroposterior and lateral X-rays of the humerus. Preoperative clinical assessments included an evaluation of RN function, focusing on wrist and finger extension and sensory function in the first web space. These assessments were repeated postoperatively to monitor any changes in nerve function. Intraoperative data were documented by the surgical team, including the specifics of the surgical approach, the type of fixation used, and any complications encountered.

Data Management and Analysis

Data from the clinical assessments, radiographs, and surgical records were entered into a Microsoft Excel spreadsheet and subsequently analyzed using SPSS version 26. Descriptive statistics were used to summarize the characteristics of the study population and the outcomes of the surgical procedures. Continuous variables were presented as means and standard deviations, while categorical variables were summarized using frequencies and percentages. The independent samples t-test was applied to compare the means of continuous variables between the two groups, and the Chi-square test was used to evaluate associations between categorical variables. A p-value of less than 0.05 was considered statistically significant.

Official and Ethical Approvals

Prior to initiating the study, approval was obtained from the Iraqi Council for Medical Specializations, ensuring that the study adhered to national guidelines for medical research. Additionally, written informed consent was obtained from each participant after a thorough explanation of the study's objectives and procedures. Participants were assured of the confidentiality of their data, which was used solely for research purposes. Ethical considerations included ensuring that all surgical procedures adhered to standard medical practices and that patients received appropriate postoperative care. The study was conducted in compliance with the Declaration of Helsinki, emphasizing the ethical principles of respect, beneficence, and justice.

Results

This analytical cross-sectional study included 38 cases of closed humeral shaft fractures treated with ORIF using plate and screw fixation through an anterolateral approach. The mean age of the participants was 36 ± 11.2 years. Among the cases, 22 (58%) underwent RN exploration during surgery, while 16 (42%) had the procedure performed without RN exploration (Figure 1).

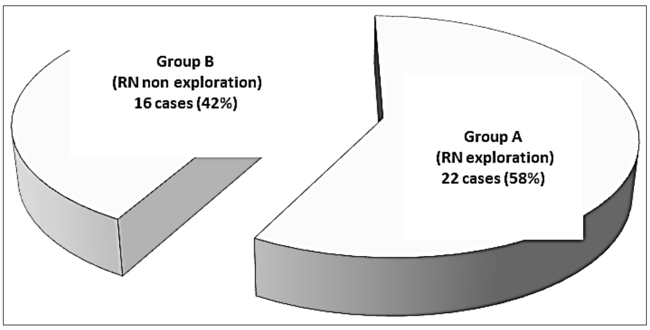

Fig 1: Distribution of studied cases according to surgery procedure

The findings of our study revealed that 6 out of 38 cases (16%) developed secondary RNP, as illustrated in Figure 2.

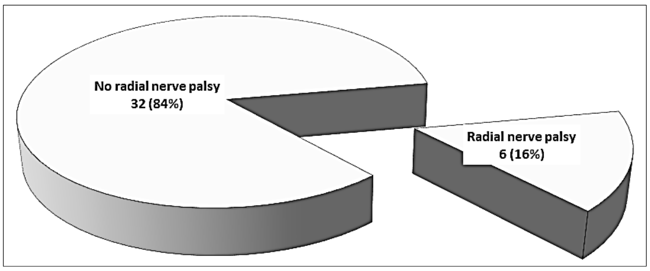

Fig 2: Distribution of radial nerve palsy among the studied cases

The association between the surgical technique and the occurrence of RNP was assessed, as shown in Table 1. Among patients who underwent RN exploration during surgery, 3 out of 22 (13.6%) developed RNP, while 19 out of 22 (86.4%) did not experience RNP. In the group without RN exploration, 3 out of 16 patients (18.8%) developed RNP, while 13 out of 16 (81.3%) did not. The difference in the occurrence of RNP between the two surgical techniques was not statistically significant, with a p-value of 0.670.

Table 1: Association between surgical technique and radial nerve palsy

		Radial Nerve Palsy				P value
		Yes 6 (16.0)		No 32 (84.0)		
Radial nerve exploration	Yes	3	13.6	19	86.4	0.670
	No	3	18.8	13	81.3	

The data presented in Table 2 compares the mean age between patients with and without RNP following surgery. Among the 38 patients included in the study, 6 (15.8%) developed RNP, while 32 (84.2%) did not. The mean age of patients who developed RNP was 33.83 years (SD = 7.4), compared to 36.44 years (SD = 11.8) in those who did not develop RNP. The difference in mean age between the two groups was not statistically significant, with a p-value of 0.608, indicating no significant association between age and the occurrence of RNP.

Table 2: Difference between mean age according to radial nerve palsy outcome

Radial nerve palsy	n.	Mean	SD	P value
Yes	6	33.83	7.4	0.608
No	32	36.44	11.8	

The study sample comprised 38 patients, with a male predominance of 27 cases (71.1%) and 11 female cases (28.9%). Regarding fracture types, Type A fractures were the most common, observed in 24 patients (63.2%), followed by Type B in 9 patients (23.7%), and Type C in 5 patients (13.2%). In terms of fracture level, the majority of fractures occurred at the middle level of the humerus, with 29 cases (76.3%), while proximal and distal fractures were less common, occurring in 3 cases (7.9%) and 6 cases (15.8%), respectively. The p-value associated with these distributions would be necessary to determine the statistical significance of any observed differences (Table 3).

Table 3: Distribution of cases according to gender, fracture type and fracture level

Variables		Frequency	%
Gender	Male	27	71.1
	Female	11	28.9
Fracture type	A	24	63.2
	B	9	23.7
	C	5	13.2
Fracture level	Proximal	3	7.9
	Middle	29	76.3
	Distal	6	15.8

The association between gender and the occurrence of RNP was analyzed. Among male patients, 3 out of 27 (11.1%) developed RNP, while 24 out of 27 (88.9%) did not. In contrast, among female patients, 3 out of 11 (27.3%) experienced RNP, and 8 out of 11 (72.7%) did not. The p-value of 0.215 indicates that the difference in RNP occurrence between males and females is not statistically significant. Regarding the type of fracture, RNP occurred in 4 out of 24 patients (16.7%) with type a fractures, 2 out of 9 patients (22.2%) with type B fractures, and 0 out of 5 patients (0.0%) with type C fractures. The p-value of 0.540 suggests no statistically significant difference in the prevalence of RNP across different fracture types. When analyzing the level of the fracture, 0 out of 3 patients (0.0%) with proximal fractures developed RNP, while 5 out of 29 patients (17.2%) with middle fractures and 1 out of 6 patients (16.7%) with distal fractures developed RNP. The p-value of 0.736 indicates that there is no statistically significant association between the fracture level and the occurrence of RNP (Table 4).

Table 4: Association between gender, type of fracture, level of fracture and radial nerve palsy

Variables		Radial nerve palsy				P value
		Yes 6 (16.0)		No 32 (84.0)		
Gender	Male	3	11.1	24	88.9	0.215
	Female	3	27.3	8	72.7	
Fracture type	A	4	16.7	20	83.3	0.540
	B	2	22.2	7	77.8	
	C	0	0.0	5	100.0	
Fracture level	Proximal	0	0.0	3	100.0	0.736
	Middle	5	17.2	24	82.8	
	Distal	1	16.7	5	83.3	

Discussion

RNP is frequently associated with high-energy fractures of the humeral shaft, but it can also occur as a complication following ORIF of such fractures. This iatrogenic or secondary RNP typically has an incidence rate of approximately 10-20% [5]. In our study, which involved 38 cases of humeral shaft fractures treated with a lateral condylar plate (LCP) via an anterolateral approach, the rate of secondary RNP was observed to be 16%. This rate aligns with the range reported in several international studies [5, 7].

Hendrickx *et al.* [17]. Conducted a systematic review encompassing 1,758 patients with closed humeral shaft fractures and reported a secondary RNP rate of 3% (14 out of 467 patients) when using the anterolateral approach. Their review included 40 studies, with 15 specifying the use of the anterolateral approach but not detailing RN identification or exploration during fixation surgery. The discrepancy between their lower reported rate and our study's findings could be attributed to the smaller sample size in our study, which might affect the observed incidence of nerve palsy.

Our findings are consistent with those of Shabir *et al.* [18], who reported a 16% incidence of secondary RNP in their descriptive study of 66 patients with humeral shaft fractures. Shabir *et al*. attributed their findings to several potential factors, including the varying levels of the operating surgeon's experience, excessive dissection of the nerve, and improper placement or use of implants and retractors.

Regarding demographic distribution, the mean age of patients in our study was 36±11.2 years, with 27 males (71%) and 11 females. This contrasts with the study by Belayneh *et al.* [19], which reported a mean age of 55.8 years with 30 males and 43 females, and the study by Mahesh and Guruprasad [20], where the mean age was 32.5 years with 16 males and 4 females. Our analysis revealed no significant association between age and gender with the occurrence of secondary RNP (p-values of 0.608 and 0.215, respectively), which is consistent with the findings of these studies.

In terms of fracture type and level, our study categorized 24 cases (63%) as type a fractures, 9 cases (23%) as type B, and 5 cases (13%) as type C according to the AO classification. Fracture levels were proximal in 3 cases, middle in 29 cases, and distal in 6 cases. Our results indicated that neither fracture type (p-value = 0.540) nor fracture level (p-value = 0.736) significantly impacted the occurrence of RNP. This aligns with Lee *et al.* [21], who found no significant association between these variables and secondary RNP, and Gous *et al.* [22], who observed that type A fractures were more commonly associated with postoperative deficits, while type C and proximal fractures did not result in RNP.

Surgical technique plays a crucial role in managing RNP. Surgeons who chose to explore the RN aimed to maintain visibility during surgery to prevent injury from reduction tools, relieve tension on the nerve, and ensure the nerve was not pinched by fracture fragments or the plate. Conversely, those who opted not to explore the nerve sought to avoid potential injury from the exploration itself, which could compromise the nerve's blood supply or cause excessive traction.

Our study showed no significant association between the type of surgical technique (RN exploration vs. non-exploration) and the rate of secondary RNP (p-value = 0.670). Henry's original work suggested that not exploring the nerve, by splitting the brachialis muscle, acts as a protective cushion against nerve injury, citing only a single RNP case [22]. In our study, non-exploration during the anterolateral brachialis splitting approach resulted in 3 cases (13.6%) of secondary RNP. This suggests that nerve injuries might be attributed to factors such as patient positioning, use of reduction tools, or entrapment between fracture fragments or under the plate.

Belayneh *et al.* [19]. Found a significantly lower incidence of secondary RNP (2.7%) when the nerve was explored during surgery. Despite this difference, it is important to note that no method guarantees complete prevention of nerve injury. Reichert *et al.* **[23]** recommended merely visualizing the nerve without separating it from surrounding tissues to reduce nerve damage risk. Wang *et al.* [24] noted that exposure and protection of the nerve do not guarantee prevention of RNP and may lead to fibrosis.

In our study, 22 cases involved RN exploration, with 3 cases (18.8%) of secondary RNP. This indicates that exploration did not significantly reduce nerve injury compared to non-exploration. Suhas *et al.* [25] performed surgery using an anterolateral approach without nerve exploration but released the lateral intermuscular septum to facilitate nerve mobility, reporting no RNP cases. Schwab *et al*. [26] highlighted that traction and movement during anesthesia and the use of retractors could cause RNP. Shon *et al*. [27] found a higher incidence of RNP with posterior approaches compared to anterolateral approaches, recommending the latter unless specific conditions warrant the posterior approach.

Conclusions

This study evaluating RNP in patients with closed humeral shaft fractures treated with ORIF reveals a 16% incidence of secondary RNP. The analysis of surgical techniques showed no statistically significant difference in RNP rates between patients who underwent RN exploration and those who did not. Furthermore, demographic factors such as age and gender, as well as fracture type and level, did not significantly influence the occurrence of RNP. These findings align with existing literature, indicating that while RN exploration is a common practice, it does not substantially reduce the risk of RNP. Future studies may benefit from larger sample sizes and further investigation into alternative surgical techniques and their impact on nerve injury.

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