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Original Scientific Paper

RADIAL NERVE INJURIES AFTER HUMERAL SHAFT FRACTURE – A SINGLE CENTER EXPERIENCE

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SUMMARY – The radial nerve anatomical positioning as it wraps around the distal portion of the humeral shaft in contact with the bone is the reason for its high incidence of injury during fracture. Traumatic radial neuropathy regresses spontaneously, but in certain cases surgical intervention may be necessary to achieve neurological recovery. The aim of this study was to present our experience in the treatment of radial nerve injuries associated with humeral shaft fracture. We performed a retrospective study of 20 cases of radial nerve injury after humeral fracture, all of which were managed surgically. We evaluated several factors such as neurological status, electromyoneurography results, time of treatment, surgical techniques, type of radial nerve surgery performed, and clinical outcomes. Our primary outcome measure was the incidence of traumatic radial neuropathy, while secondary outcome was focused on nerve recovery. Out of 166 operations for humeral shaft fractures performed during a ten-year period, 20 patients were identified for this study. The average age of patients was 32 (±22) years. The largest number of fractures (83%) were initially stabilized by open reduction. The fractures were in the mid third of the shaft in 11 (55%) cases and in distal third in 9 (45%) cases. Primary nerve injury was present in 15 (75%) patients, while iatrogenic radial nerve injury occurred in 5 (25%) patients. The mean DASH score was 9±15, with 90% of patients regaining their previous level of physical activities. In conclusion, in a shaft humeral fracture, radial nerve lesion symptoms may be seen and resolve in most cases. If neurological symptoms do not improve, electromyoneurography can be employed to assess the degree of nerve damage. Surgical intervention is indicated if there is no functional recovery after three months of conservative management.

Keywords: *Traumatic radial neuropathy; Humeral shaft fracture; Surgical treatment*

Introduction

Traumatic radial neuropathy is the most common peripheral nerve injury in long bone fractures[1]. The radial nerve anatomical positioning as it wraps around the distal portion of the humeral shaft in contact with the bone is the reason for its high incidence of injury

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during the fracture[2]. Traumatic radial neuropathy is a serious posttraumatic complication, with an overall prevalence of 12.3% among 7262 fractures[3,4]. Specific studies have reported the incidence of traumatic radial neuropathy at 11.8% in a population of 4517 humeral fractures[5] and 16.3% among 1882 cases of humeral shaft fractures[6]. Traumatic neuropathy regresses spontaneously, but in certain cases surgical intervention may be necessary to achieve neurological recovery. Surgical intervention and fracture repair have demonstrated a radial nerve recovery rate of 89%[7].

According to data from previous studies, there is no significant difference in recovery rates between early surgical intervention and those with delayed surgery[8,9]. Iatrogenic radial nerve neuropathy after humeral shaft non-union repair is even more common than expected[10]. Nerve injury classification according to Seddon and Sunderland assists in prognosis and determination of treatment strategy for nerve injuries[11]. Patients with severe peripheral nerve injuries often face poor nerve regeneration and incomplete functional recovery, even after surgical nerve repair[12]. Running laterally along the spiral groove of the humerus, the radial nerve is vulnerable to compression or injury from fracture[2,13]. Such injuries can lead to neurological deficits distal to the point of injury. The most common presentation of this vulnerability results in the inability to extend the hand[14].

The aim of this article is to present our experience in the treatment of radial nerve injuries in humeral shaft fracture.

Patients and Methods

We performed a retrospective analysis of twenty cases of radial nerve injury following humeral fracture, all of which were treated surgically. We recorded neurological status, electrophysiological finding, incidence of traumatic radial neuropathy, time of treatment, surgical management, and clinical outcomes. Primary traumatic radial neuropathy was observed immediately after humeral fracture, while secondary or iatrogenic neuropathy occurred after orthopedic intervention in neurologically preoperatively intact patients.

Inclusion criterion were patients surgically treated during a ten-year period with a minimum follow-up duration of one year. Eligible patients had unilateral non-pathological humeral shaft fracture and exhibited unilateral radial neuropathy due either to the fracture itself or as a result of orthopedic management. We excluded cases of compressive neuropathy, radial nerve injury not associated with humeral shaft fracture, and patients with a prior history of peripheral nerve sheath tumor or neuropathy from other reasons.

Surgical intervention was recommended if there was no functional recovery of the radial nerve after 3 months of conservative treatment. Subsequently, we analyzed the primary or secondary radial neuropathy recovery rate and radial nerve motor function recovery time. Anteroposterior and lateral radiological projections through imaging studies were sufficient for diagnosis and treatment. In patients with displaced unstable humeral fractures with good bone quality, osteosynthesis was the preferred treatment choice.

The goal of surgical treatment of humeral shaft fractures was to restore anatomic alignment and the relationship between the two columns and the articular surface through stable fixation, with reconstruction plates being a valid option to improve the quality of osteosynthesis[15].

Rehabilitation was started postoperatively. In the case of wrist drop or the inability to extend the hand, electromyoneurography (EMNG) is indicated one month after surgery[16]. If the electrophysiological findings showed signs of a radial nerve lesion without recovery after follow-up examinations, surgical exploration of the nerve was indicated. Final outcome was evaluated by muscle strength assessment using Disabilities of Arm, Shoulder and Hand (DASH) score. The DASH score consists of 30 questions and is used to assess functional disorders of the upper extremity. The outcome was evaluated after discharge from the hospital and during outpatient clinic evaluation. Detailed neurological examination was performed to notice specifically the presence or absence of any neurological deficit. All patients had electrophysiological follow-up as well.

Surgical approach

Surgical exploration of the radial nerve was carried out with the patient in supine or lateral position. The procedure was carried out under general anesthesia and with an arm stabilizer support. The approach is

determined by the orthopedic scar incision through which previous osteosynthesis was performed. The entryway to the elbow and distal humerus was the back. Using a microsurgical technique, the radial nerve was identified at the level of spiral groove of the humerus and prepared distally and proximally. Scar resection, decompression and removal of adhesions were made by exploration, as well as external and internal neurolysis. In the case of interruption of the nerve continuity, after debridement a termino-terminal anastomosis was performed with the help of microsutures. In the case of a nerve gap, it is bridged with the help of a sural nerve graft. Immobilization period varied based on the intraoperative finding. In the case of termino-terminal anastomosis, the patient's clinical evaluation should not exceed 14 days. Early mobilization influences the final range of motion and promotes nerve gliding, thereby minimizing the formation of perineural adhesions and the risk of postoperative neuropathy. Self-adjusting articulated orthosis was used to enable patients to initiate movement early within a controlled range under the supervision of both the surgeon and therapist.

Data analysis primarily focused on the incidence of traumatic radial neuropathy caused by the fracture and displacement of the supracondylar humerus. A secondary analysis focused on the risk of nerve lesions caused by osteosynthetic material.

Results

The series included 20 patients out of 166 humeral shaft fractures operated on between December 2013 and December 2023. Average patient age was 32 (±22). Males represented 13 (65%) of all patients. The left side was injured in 12 (60%) patients. The largest number of subjects suffered a fracture in the spring and summer months. The largest number of fractures were stabilized initially by open reduction (83%). The fractures occurred in either the middle or lower third of the humeral diaphysis. The fractures were located in mid third of the shaft in eleven (55%) and distal third in nine (45%) cases. Typically, fixation was achieved through plate fixation or nailing, with five cases resulting in iatrogenic injury, three of these following plate fixation and two following nailing.

Surgical procedure was performed three months after orthopedic operation. Radial nerve exploration revealed compression at the intermuscular septum in fifteen cases and direct conflict with the fixation material in five cases. Neurolysis was necessary in eighteen cases, termino-terminal anastomosis and nerve grafts in one case each. Mean delay of surgical treatment was one day (zero to two days).

Primary nerve injury was observed in fifteen (75%) patients (Fig. 1), while iatrogenic nerve injury occurred in five (25%) patients (Fig. 2). Among the patients studied, fifteen (75%) patients acquired complete traumatic radial neuropathy, while five (25%) patients acquired incomplete neuropathy. In two (10%) patients, total nerve transection was treated by end-to-end anastomosis (Fig. 3) and sural nerve grafting, respectively. Nerve surgery outcomes were evaluated at a mean follow-up of one year. The mean time to recovery was fifteen months following neurolysis and twenty months after nerve end-to-end anastomosis or grafts. Bone healing was achieved in all cases. The mean DASH score was 9±15 (0-100), and 90% of patients successfully regained their previous level of physical activity.

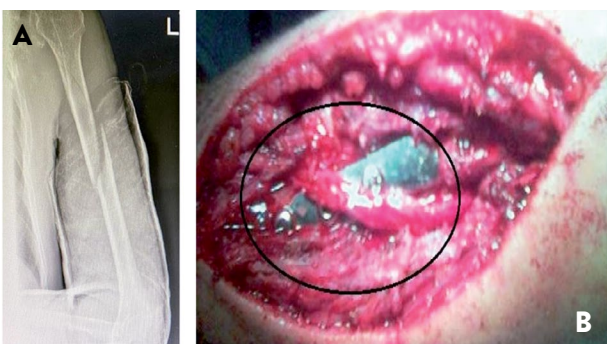

Fig. 1. An 18-year-old patient was operated on for humeral shaft fracture of the left arm (A). Wrist drop and the inability to extend the hand was recorded after repositioning and osteosynthesis with a plate. Electromyoneurography showed signs of the radial nerve lesion. Scar resection, nerve decompression and external neurolysis were performed with good postoperative recovery (B).

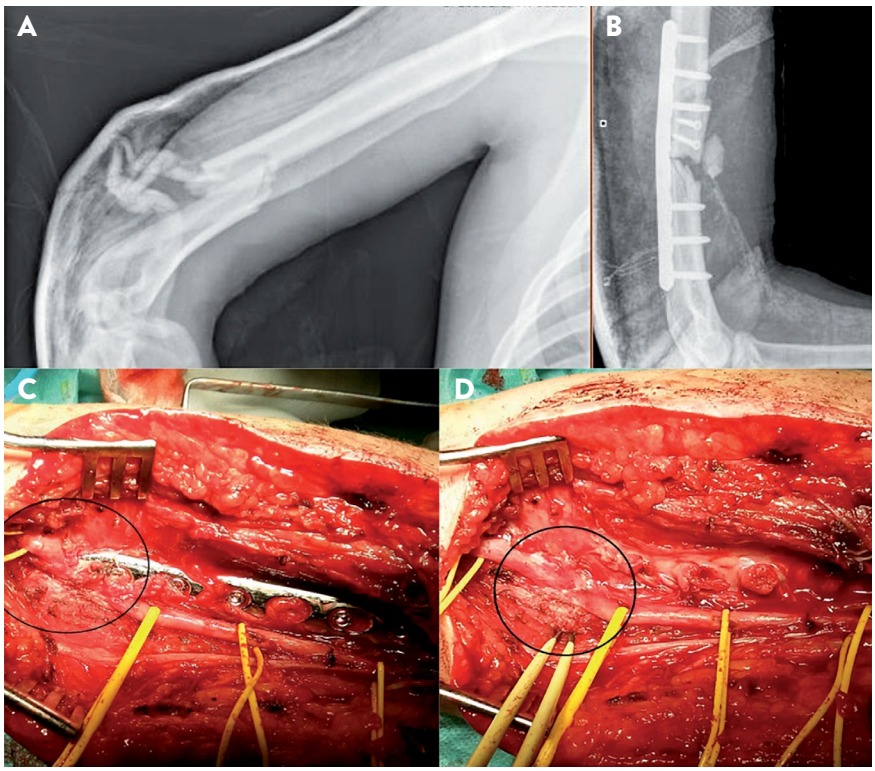

Fig. 2. A 25-year-old man was operated on for distal humerus fracture of the left arm (A). Repositioning and osteosynthesis with a plate were performed (B). Neurological and electrophysiological findings established the diagnosis of palsy of the muscles innervated by the radial nerve. Electromyoneurography confirmed the lesion. Intraoperatively, radial nerve compression caused by the osteosynthetic plate was recorded (C). After removing the plate, the nerve was decompressed (D). Additional external and internal neurolysis was performed. The patient had good recovery after rehabilitation.

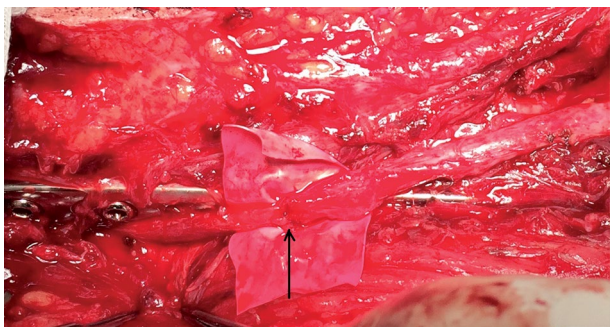

Fig. 3. A 38-year-old patient was operated on for diaphyseal fracture of the right arm. Reduction of displaced humeral fracture followed by osteosynthetic fixation was performed. Persistent wrist drop and the inability to extend the hand without signs of electrophysiology recovery indicated exploration. Intraoperative finding revealed radial nerve interruption which required end-to-end anastomosis. Postoperative outcome was rated fair.

Discussion

The incidence of nerve injury that required surgical treatment after humeral shaft fracture was 12%. All patients experienced improvement in their nerve function with a median time to recovery of ten months. Operative treatment of the fracture influenced nerve recovery[17]. The literature from 1964 to 2017 indicates that patients who underwent surgical exploration within 3 weeks of injury had a significantly higher chance of regaining radial nerve function compared to those managed non-surgically or with late surgical exploration[18-21]. These findings align with previous studies on outcome predictors in traumatic radial neuropathy[7,22]. Severe fracture displacement and high-grade wounds may contribute to gross nerve lesions[23,24].

The incidence of traumatic nerve injury varies substantially, ranging from 2% to 35%. The most common complication associated with displaced fractures of the humerus is neurapraxia. Iobst *et al.* report that radial nerve injury outnumbers all other traumatic neuropathy[25]. In the literature, the risk of specific nerve

injury with regard to the median, anterior or posterior interosseous, radial, and ulnar nerves has not been well defined. Reports of neurapraxia vary, with some studies indicating rates from 0% up to 10% for radial nerve[26]. More specifically, the weighted event rate of neurapraxia was 4.1% for the radial nerve[27].

There are more studies about humeral fractures. The incidence of neurological injury after extension type of humeral fractures is about 12%. Non-dominant arm is more frequently involved[28], as also found in our study.

In some study populations, radial nerve is the most common injured nerve. In a meta-analysis by Babal *et al.*, the overall incidence of neurapraxia for displaced fractures of the humerus was 11.3% of 5148 patients. In the same study, with respect to iatrogenic neurapraxia, the incidence of neuropathy at an overall weighted rate of 3.9% was recorded among 1303 patients. Among 476 patients treated with closed reduction and laterally placed percutaneous pins, the unweighted event rate of neurapraxia was 1.9% and 2.2% for the radial nerve[27].

Radial nerve injuries accounted for 27.3% of all iatrogenic neurapraxia induced by lateral pinning, while radial neuropathy represented 4.8% of all nerve injuries induced by medial/lateral pinning[29]. Early exploration of the nerve is crucial if nerve function deteriorates following closed reduction and pinning due to the risk of nerve entrapment or iatrogenic injury[30,31]. Extraction of the nerve from the fracture or from constricting structures and removal of any compromising hardware should be performed as soon as possible[32].

The actual rates of nerve injury we report almost certainly underestimate the incidence of neuropathy. Our study was retrospective in nature as nearly all studies included in meta-analysis are[27]. Documentation of neurological status is not standardized across individual observers. The study could have been improved with prospective and randomized control.

Unique features observed in our series included compression in the intermuscular septum and iatrogenic lesions, warranting differentiation. If necessary, exploration surgery with nerve graft preparation should be considered[33,34]. We found entrapped radial nerve injuries in the fracture site by nerve exploration. Humeral shaft fracture is a common problem and surgeons have to deal with such fractures sometimes burdened by severe complications[35]. The precise diagnosis of the fracture and appropriate preoperative planning allow selection of the most convenient surgical approach and most appropriate arrangement of osteosynthesis[36]. Training of the treating team could reduce surgical complications and obtain stable fixations[37]. This enables early rehabilitation and mobility, thus reducing the rate of complications and acute neuropathic pain which is often the primary cause after nerve injury[38].

We compared the results of our study with recent studies that analyzed surgical treatment of radial nerve lesions due to humeral shaft fractures[7,15]. Similar results indicate a more severe nerve lesion in younger patients due to higher force energy leading to humeral shaft fractures with more severe consequences. The unfavorable position of the fragments makes it difficult for the fracture to heal and for the radial nerve to recover. In such cases, there is a greater possibility of secondary traumatic radial neuropathy, which requires early surgical exploration of the radial nerve. Considering previous studies on the association of humeral shaft fracture and radial neuropathy, nerve exploration should not be delayed for longer than 3-6 months[7].

Advanced imaging modalities such as ultrasound and magnetic resonance neurography are increasingly used by upper extremity surgeons to diagnose and evaluate peripheral nerve pathology and often provide complimentary information[39,40]. Enhancements in imaging technology provide more precise information on the peripheral nervous system, allowing for more accurate diagnoses and preoperative planning[41].

Conclusions

In shaft humeral fracture, radial nerve lesion symptoms may be seen, with many cases resolving spontaneously with conservative treatment. However, if neurological symptoms do not improve over time, electromyoneurography is recommended to access the extent of radial nerve damage. Surgical intervention is advised if there is no functional recovery of the radial nerve after 3 months of expectant management. When managed appropriately, nerve recovery and clinical outcomes are favorable. Satisfactory outcomes are usually limited to relatively minor injuries and reflect neurapraxia or axonotmesis.

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Sažetak

OZLJEDE RADIJALNOG ŽIVCA NAKON PRIJELOMA DIJAFIZE HUMERUSA – ISKUSTVO JEDNOG CENTRA

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Anatomski položaj radijalnog živca koji prolazi oko distalnog dijela dijafize nadlaktične kosti u kontaktu s kosti razlog je visoke učestalosti njegovih ozljeda tijekom prijeloma. Paraliza se spontano povlači, ali u određenim slučajevima neophodna je kirurška intervencija kako bi se postigao neurološki oporavak. Cilj ovog rada je prikazati naša iskustva u liječenju ozljeda radijalnog živca kod prijeloma dijafize humerusa. Proveli smo retrospektivnu studiju analizirajući 20 slučajeva ozljede radijalnog živca nakon prijeloma nadlaktične kosti liječenih kirurški. Analizirali smo neurološki status, elektromioneurografiju, vrijeme liječenja, kirurški pristup, tip operacije radijalnog živca i klinički oporavak. Primarni ishod bila je incidencija traumatske paralize živca, a sekundarni je bio oporavak živca. Istraživanjem je obuhvaćeno 20 bolesnika od 166 prijeloma dijafize humerusa operiranih u razdoblju od deset godina. Prosječna dob bolesnika bila je 32 (±22) godine. Najveći broj prijeloma stabiliziran je inicijalno otvorenom repozicijom (83%). Prijelomi su bili smješteni u srednjoj trećini dijafize u 11 (55%) i u distalnoj trećini u 9 (45%) slučajeva. Primarna ozljeda živca bila je prisutna u 15 (75%) slučajeva, dok se sekundarna (jatrogena) ozljeda živca dogodila u 5 (25%) slučaja. Od ukupnog broja ispitanika 15 (75%) je imalo plegiju, dok je 5 (25%) imalo parcijalnu paralizu živca. Srednja vrijednost skora DASH bila je 9±15, a 90% bolesnika uspjelo se potpuno oporaviti. U zaključku, kod prijeloma dijafize nadlaktične kosti mogu biti prisutni simptomi lezije radijalnog živca koji se u većini slučajeva spontano oporavljaju. Ako neurološki deficit ustraje indicirana je elektromioneurografija kako bi se utvrdio stupanj oštećenja. Kirurška intervencija je indicirana ako nema funkcionalnog oporavka nakon tri mjeseca konzervativnog liječenja.

Ključne riječi: *Ozljede radijalnog živca; Prijelom dijafize humerusa; Kirurško liječenje*