Trauma Case Reports 44 (2023) 100789

Contents lists available at ScienceDirect

Trauma Case Reports

journal homepage: www.elsevier.com/locate/tcr

Radial nerve contrast fluoroscopy combined with ultrasound imaging for humeral shaft fracture☆

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ARTICLE INFO

Keywords:
Humeral shaft fracture
Radial nerve
Contrast fluoroscopy
Ultrasound imaging

SUMMARY

Ultrasonography is an alternative method for detecting the nerve tract in real-time. However, bones and soft tissues can encounter imaging difficulties because of the occasional blockade. Humeral shaft fracture can be addressed using several approaches, including open plate fixation and intramedullary nailing. Nevertheless, these methods are associated with a risk of radial nerve injury due to the presence of nerve tracts around the middle part of the humeral shaft. Here, we present a patient who underwent intramedullary nail fixation in the beach-chair position converted into open plate fixation in the prone position based on the radial nerve course on preoperative fluoroscopic evaluation. Combined fluoroscopy and ultrasonography of the fracture site facilitated the detection of anatomical structure disruption around the nerve and the safe completion of surgery. The nerve delineation technique with contrast-enhanced radiographic effects can prevent the risk of nerve injury.

Introduction

Adult victims in traffic accidents often suffer humeral shaft fractures [1]. These fractures are associated with a risk of radial nerve injury due to the radial nerve tract around the middle of the humerus. Therefore, definitive anatomical evidence of disrupted nerve travel must be obtained to plan surgical strategies for preventing inotropic nerve damage [2]. The following surgical techniques are used: open reduction and internal fixation (ORIF) with plating using the anterior approach in the supine position and closed reduction and internal fixation with intramedullary nailing in the beach-chair position. The safety of ORIF in the prone position is due to the easier visualization and accessibility of the radial nerve than intramedullary nailing, which is less invasive for skin, muscle, and soft tissues. Whichever method is employed, these methods must detect the course of the radial nerve to prevent surgical nerve injury, and the preoperative position of the patient should be changed. Here, we report a case of a humeral shaft fracture in which the radial nerve tract was observed preoperatively by contrast radiography and ultrasonography, and preoperative surgical policy reversal prevented the radial nerve damage involved in the fracture site of the humeral shaft.

Case presentation

A man in his late teens (height: 185 cm, weight: 80 kg), who had no medications or past medical history, was involved in a road

☆ The case was presented at the 68th Annual Meeting of the Japanese Society of Anesthesiologists in Kobe, Japan, on 3rd June 2022.

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https://doi.org/10.1016/j.tcr.2023.100789
Accepted 5 February 2023
Available online 7 February 2023

traffic accident. He then sustained several traumas, including head injury, multiple rib fractures, pelvic fractures, and a right humeral shaft fracture. A computed tomography scan revealed a small intraventricular hemorrhage and multiple minor brain contusions, indicating diffuse axonal injury. He was intubated due to unstable consciousness (Glasgow coma scale score of 6) and irregular breathing and was placed under deep sedation to prevent brain swelling and cerebral hypertension. Brain swelling and respiratory status deterioration after twodays of monitoring were not observed.

The humerus was fractured into three pieces at the metaphysis and was deformed dorsally. The fracture was classified as 12-B3 (fragmented wedge fractures) based on the AO/OTA fracture classification system (Fig. 1). Motor and sensory deficits could not be evaluated because of loss of consciousness due to sedation. Initially, the patient was scheduled to undergo fracture repair with an intramedullary nail. However, the fracture site could have entrapped the radial nerve. Hence, preoperative contrast-enhanced fluoroscopy was performed to detect the radial nerve tract after his family informed consent.

After admission to the surgical room and the administration of brachial plexus block interscalene with 5mL of 0.5 % levobupivacaine under ultrasonography guidance, the radinerve's ultrasound delineation was performed distally from the axilla, elbow, and fracture site (Fig. 2). However, from ~5 cm proximal to the fracture site, the radial nerve suddenly became difficult to detect and trace. Next, we confirmed that the radial nerve was surrounded by the brachioradialis and humerus muscles at the elbow. Nevertheless, it was also untraceable ~5 cm distal to the fracture site. We assumed from the images that the radial nerve might be disrupted or lodged in the fracture site. Therefore, the anatomical dislocation of the radial nerve was identified using contrast-enhanced radiography. We

Fig. 1. The initial plain radiograph of fracture; AO classification 12-B3 fragmented wedge fracture of right humerus shaft fracture.

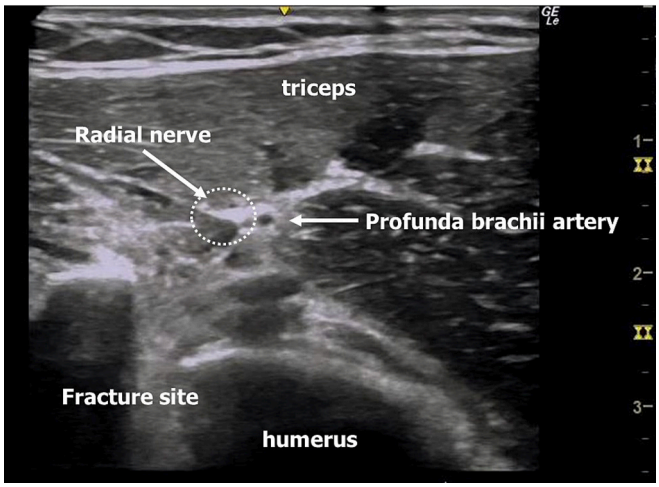

Fig. 2. Ultrasonography and anatomical caption of the humerus shaft and radial nerve at 5 cm distal from the fracture site. From this point, we could not trace the radial nerve course close to the fracture site.

administered the contrast agent with 4 mL of iohexol (Omnipaque240, GE Healthcare, Chicago, IE, USA) around the radial nerve with ultrasonography guidance at the distal end to visualize the nerve above the fracture site. The contrast agent spread caudally along the radial nerve and leaked into the fracture site (Fig. 3). Furthermore, similar spread and leakage were observed after the injection of an additional contrast medium around the radial nerve at 5 cm distal to the fracture site.

We decided to change the surgical technique from the nail fixation on the anterior approach in the supine position to the plate fixation on the posterior approach in the prone position because of the possibility of nerve dislocation. The surgeons made an incision on the brachium's posterior midline, and the triceps were split to identify the dorsal humerus. The radial nerve was strayed toward the inside of the fracture and was compressed by the distal and proximal bone fragments (Fig. 4). All bone fragments were realigned and fixed with a plate within 150 min of surgery.

After extubation, the patient received nonsurgical treatment for multiple traumas, and he was transferred to the rehabilitation ward on postoperative day 14. He presented with sensory dullness and motor deficits in the radial nerve region. However, he could accomplish the subsequent rehabilitation activities and was discharged on postoperative day 60. Upon his return to his distant residence from our institution, it became unfeasible to conduct a follow-up assessment, including an imaging evaluation (Fig. 5). However, after two years, our follow-up letter confirmed that he had improved his upper limb movement and had seamlessly reintegrated into society without any hindrance to his daily activities.

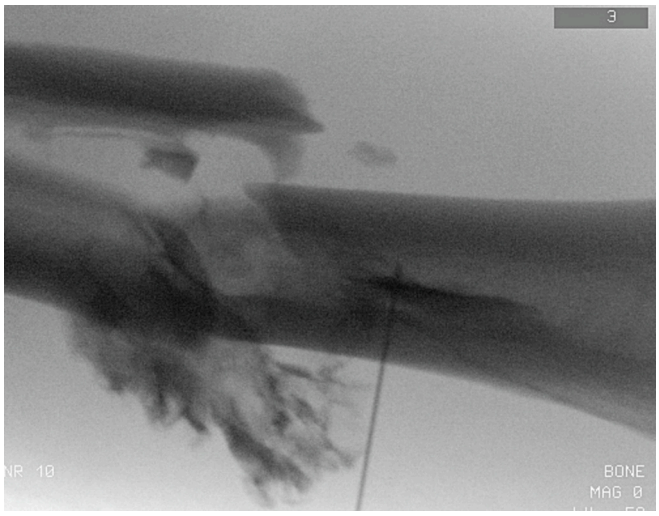

Fig. 3. Contrast fluoroscopic image of the radial nerve and fracture site. Proximal injection of contrast agent around the radial nerve spread into the fracture site and deviated the nerve course.

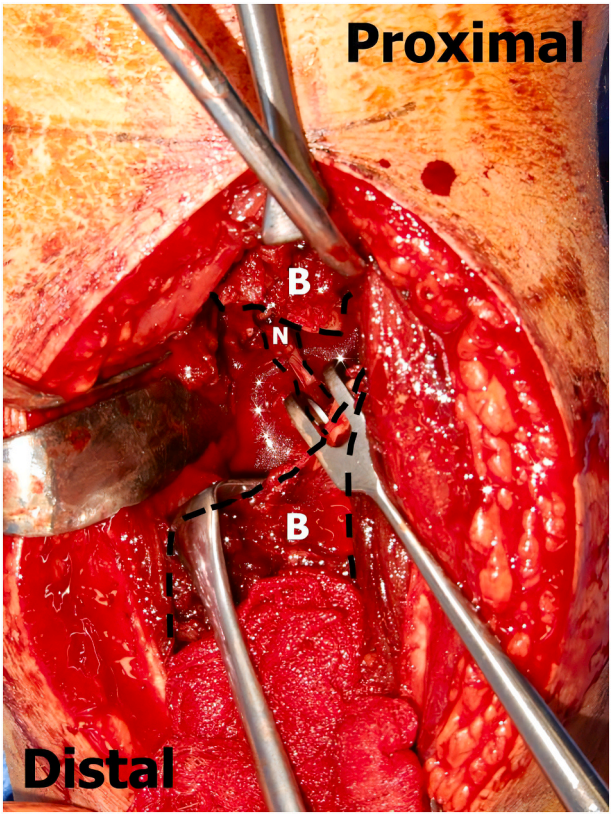

Fig. 4. Photograph of the surgical field showing the radial nerve straying the fracture site from the lateral to the medial side of the humerus. "B" means bone fragments of the humerus, and "N" means the dislocated radial nerve.

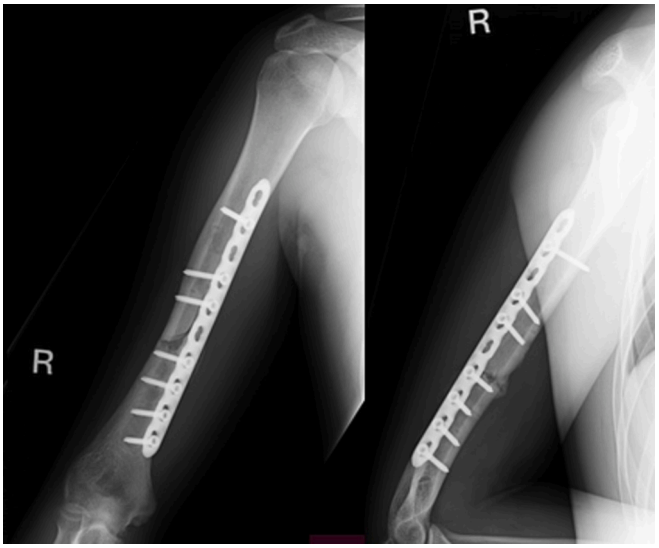

Fig. 5. Radiograph of right upper arm at 3 months postoperatively.

Discussion

Here, we describe a humeral shaft fracture in a patient who underwent combined peripheral nerve contrast-enhanced fluoroscopy, which could detect radial nerve misalignment and prevent surgical nerve rupture. This nerve-detecting procedure helped change the

surgical position to prevent iatrogenic radial nerve injury.

Approximately 10 %–17 % of patients develop radial nerve injury induced by humeral shaft fractures, and the incidence of iatrogenic radial nerve palsy could reach up to 7 % [3,4]. In the current case, we primarily suspected that the radial nerve was lodged in the fracture site. The risk of nerve entrapment and damage during fracture repair was a cause of concern. Nail fixation is an excellent technique as it has a shorter surgical time and good aesthetic outcomes. It can prevent infection and is associated with relatively minimal postoperative pain due to small incisions. However, it has a higher complication rate and technical difficulty than plate fixation [5]. Meanwhile, a previous meta-analysis showed that nail and plate fixation differences were insignificant in fracture union, radial nerve injury, and infection [6].

Ultrasonography with an 8–12-Hz high-frequency transducer can detect nerve travel if the fractured bone fragments do not interfere with imaging. Seventeen case studies revealed the efficacy of ultrasound imaging for accurately evaluating the radial nerve to prevent compression or entrapping [7]. However, fluoroscopic imaging of peripheral nerve defects is rarer than the nerve root and spinal defects during pain management procedures [8]. Ultrasonography prevents radiation exposure and painful procedures and can be used to evaluate soft tissue morphology and bone structures. However, the bone has a significantly different acoustic impedance than soft tissue, and the area embedded in the bone fragment is challenging to assess because ultrasound waves are primarily reflected at their boundary and do not propagate beyond them.

Contrast-enhanced fluoroscopy shows transparent and three-dimensional anatomical structures. Ultrasonography, a peripheral nerve block procedure, was used to search for the normal radial nerve proximally and distally from the fracture site. Fluoroscopic imaging of the fracture site, which was not visualized on ultrasonography, detected the disruption of the anatomical structures around the nerve. Combined imaging is advantageous as it is a safe procedure in cooled radiofrequency hip denervation therapy for chronic pain syndrome [9] and has fewer procedures and lesser complications in transjugular kidney biopsy [10]. Further, it could provide accurate information on nerve travel while assessing the fracture site.

In conclusion, the double-imaging techniques can prevent iatrogenic radial nerve injury by converting the surgical approach. Contrast-enhanced fluoroscopy, one of the final evaluation methods before surgery in the operating room, can help avoid intraoperative changes in surgical strategy and improve surgical quality.

Acknowledgment

All authors have no conflict of interest with any organizations.

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