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CASE REPORT

A rare case of type 2 entrapment of the median nerve after posterior elbow dislocation with MRI and ultrasound correlation

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Abstract
A 9-year-old boy sustained an ulnohumeral dislocation with a medial epicondyle fracture and experienced incomplete post-traumatic median nerve palsy in addition to post-traumatic stiffness following closed reduction and cast immobilization. When his motor palsy and stiffness did not improve, MRI and ultrasound were obtained, which demonstrated entrapment of the median nerve in an osseous tunnel at the fracture site, compatible with type 2 median nerve entrapment. Subsequently, the patient underwent surgery to mobilize the medial epicondyle and free the median nerve, resulting in improved range of motion, near complete restoration of motor function, and complete restoration of sensory function in the median nerve distribution within 6 months of surgery. Median nerve entrapment, particularly intraosseous, is a rare complication of posterior elbow dislocation and medial epicondyle fracture that may result in significant, sometimes irreversible, nerve damage if there is a delay in diagnosis and treatment. A high degree of clinical suspicion with early imaging is indicated in patients with persistent stiffness or nerve deficits following reduction of an elbow dislocation. Intra-articular entrapment diagnosed on ultrasound has been reported and intraosseous entrapment diagnosed clinically and on MR neurography have been reported; however, to our knowledge, this is the first reported case of intraosseous (type 2) median nerve entrapment clearly visualized and diagnosed on traditional MRI and ultrasound. The use of ultrasound for diagnosing median nerve entrapment is an accurate, accessible, and non-invasive imaging option for patients presenting with suspected nerve entrapment following elbow dislocation.

Keywords Median neuropathy · Elbow · Joint dislocations · Ultrasound · Magnetic resonance imaging

Introduction

Medial epicondyle fractures are common in the pediatric population, accounting for 12% of all elbow fractures, and are often seen following ulnohumeral dislocation [1, 2]. They may occur as a result of direct trauma to the medial epicondyle, avulsion from valgus or hyperextension injuries, or elbow dislocation events [3, 4]. The medial epicondyle is the anatomical origin of the common flexor tendons in addition to palmaris longus, a portion of pronator teres, and the ulnar collateral ligament [5]. As a result of traction from these strong soft tissues, when the medial epicondyle is fractured, the fracture fragment is typically displaced distally, resulting in physeal widening seen on radiographs [6].

Potential complications of ulnohumeral dislocation include elbow stiffness, decreased range of motion, and damage to the neurovascular structures around the elbow. Injuries of the ulnar nerve are not common, seen in 6.3% of elbow dislocations in one series [7], and may occur secondary to traction at the time of trauma or compression from a displaced fracture fragment. Median nerve injuries are even less common, but entrapment of the median nerve or its motor branch, the anterior interosseous nerve, within the elbow joint or within an osseous bridge formed by healing medial epicondyle fracture, may occur after elbow dislocation [7–9].

An entrapped osseous fragment, seen in 5–18% of elbow dislocations, is often radiographically and clinically apparent following closed reduction [2, 10], but an entrapped nerve may be overlooked in the immediate post-operative period. Nerve entrapment should be considered if the patient has

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neurological symptoms following an elbow dislocation event, particularly if the symptoms persist [11]. Early diagnosis is critical because, although many medial epicondyle fractures are treated conservatively [12], nerve entrapment is an indication for surgical intervention [13].

Magnetic resonance imaging, particularly MR neurography, can evaluate peripheral nerves well and is widely available, but is costly and may require sedation in pediatric patients. Additionally, MRI cannot be performed in some patients with metallic debris or bioelectronic devices. Ultrasound is widely available and can assess nerve motion with dynamic imaging, apply transducer pressure to identify a Tinel's sign on ultrasound, evaluate long segments of peripheral nerves with extended field of view imaging and compare to the contralateral side. Furthermore, with the advent of high frequency transducers, the spatial resolution of ultrasound now surpasses that of clinically available MRI, particularly for superficial structures such as peripheral nerves. Last, ultrasound is well tolerated by pediatric patients and less costly than MRI.[14, 15] For these reasons, ultrasound may be the optimal first choice of imaging for pediatric patients with suspected nerve entrapment.

Although there have been several reports of median nerve entrapment after ulnohumeral dislocation, most of them describe type 4 (intra-articular) entrapment and rely primarily on MRI for the final diagnosis. To our knowledge, only four publications describe type 2 median nerve entrapment: the first two, diagnosed surgically and with radiographic correlation [13, 16], the third in which nerve entrapment was reportedly not visualized on imaging and diagnosed by surgical exploration 2 years after the initial injury [11], and the fourth in which two cases were diagnosed with MR neurography [17]. Although some ultrasound images were included in the fourth case review, the focus of the article was on the benefits of MR neurography, not the use of ultrasound as a primary diagnostic tool. We found only one recent case of median nerve entrapment diagnosed on ultrasound; however, this case reports the median nerve being entrapped between the medial epicondyle and ulna, more consistent with a type 1 rather than a type 2 entrapment [18]. Finally, nearly all of the previously reported cases described a delay in diagnosis, with imaging performed only when clinical symptoms did not improve over time, sometimes years after the injury [11]. Our case is unique in that we present the first case, to our knowledge, of intraosseous (type 2) median nerve entrapment after ulnohumeral dislocation with concomitant medial epicondyle fracture that is clearly visible on both traditional MRI and ultrasound.

Case report

A 9-year-old right-hand-dominant male presented to the emergency department after a fall from playground equipment and was diagnosed with a left complex ulnohumeral elbow dislocation with a displaced medial epicondyle fracture (Fig. 1a, b). He had diminished sensation with paresthesias in the median nerve distribution and loss of motor function of the flexor pollicis longus and flexor digitorum profundus to the index finger, with 0/5 motor strength in both. He underwent closed reduction and splinting in the emergency department and post-reduction radiographs demonstrated a concentric reduction with minimal fracture displacement (Fig. 1c). Shortly thereafter, his splint was converted to a cast for definitive, non-operative treatment of the fracture and dislocation and he was diagnosed with traumatic anterior interosseous nerve palsy. The family was counseled that the palsy associated with elbow dislocation should resolve at around 12 weeks and no additional imaging was indicated at the time of injury. Approximately 5 weeks after the initial injury, radiographs demonstrated osseous bridging at the fracture site and the cast was removed (Fig. 2a).

When the patient presented to the clinic 10 weeks after the initial injury, he complained of persistent elbow stiffness with decreased range of motion, demonstrating only 40–90° of flexion–extension. Furthermore, although he had improved motor function of the flexor pollicis longus and flexor digitorum profundus to the index finger, with 4/5 strength, he had persistent paresthesias in the median nerve distribution. He was started on physical therapy, but failed to make satisfactory gains in his functional range of motion. Repeat radiographs were obtained at this time that demonstrated an osseous tunnel at the fracture site (Fig. 2b). Given persistent neuropathic symptoms and decreased range of motion, additional imaging was performed.

Magnetic resonance imaging of the elbow demonstrated an abnormal course of the median nerve at the level of the elbow, with the nerve taking an abrupt posterior course at the medial epicondyle and making a hairpin turn before coursing anteriorly into the forearm, well seen on sagittal images (Fig. 3). On coronal (Fig. 4) and axial (Fig. 5) MR images, the nerve was seen coursing through an osseous tunnel formed from the abnormal healing of the medial epicondyle fracture fragment. The nerve demonstrated increased signal on T2-weighted images, but was contiguous and maintained a normal size throughout its course. The ulnar nerve, which is typically well visualized on MRI, was not well seen secondary to edema in the posteromedial soft tissues, osseous deformity from the fracture, and distended posteromedial joint capsule. There was no edema or atrophy of the visualized muscles innervated by the median nerve (Fig. 6) to suggest denervation-related muscle changes.

Ultrasound was performed for confirmation of median nerve entrapment and to assess the ulnar nerve. The median nerve was well visualized on the short axis (Fig. 7) and long axis (Fig. 8) and appeared normal in echogenicity and fascicular morphology at the level of the distal arm, but made a sharp turn posteriorly, where it became slightly hypoechoic

Fig. 1 **a** Anteroposterior and **b** crosstable lateral radiographs at the time of the initial injury demonstrate posterior dislocation of the elbow with displaced medial epicondyle fracture (*arrow*). **c** Post-reduction radiograph demonstrates concentric reduction with persistent, mild displacement of the fractured medial epicondyle (*circle*). At the time of injury, the patient had diminished sensation with paresthesias in the median nerve distribution and loss of motor function (0/5 strength) of the flexor pollicis longus and flexor digitorum profundus to the index finger

with fascicular prominence, appearing kinked as it coursed deep to the bony acoustic landmark of the displaced medial epicondyle fracture fragment. Here, for a distance of less than 1 cm, the nerve was obscured by acoustic shadowing, but was again well visualized as it exited the osseous tunnel, slightly hypoechoic in echotexture, and demonstrating a small anechoic area suggestive of intraneural edema as it coursed anteriorly into the proximal forearm, best seen on long-axis images (Fig. 8b). The course of the median nerve was especially well visualized on the short-axis, cinematic ultrasound images. Attempts at dynamic imaging with flexion and extension of the elbow were futile as the patient had a flexion deformity and minimal passive or active range of motion. The ulnar nerve was well visualized on ultrasound and appeared normal in size, echogenicity, and fascicular morphology throughout its visualized course.

To ensure that the median nerve did not become encased in bone at the termination of his growth, operative mobilization

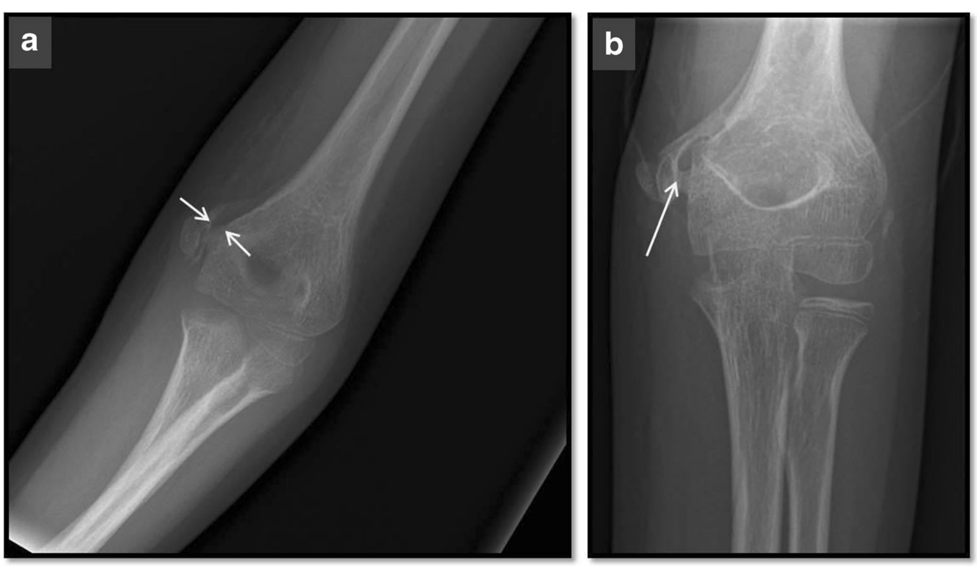

Fig. 2 **a** Anteroposterior radiograph obtained 5 weeks after initial injury demonstrates some osseous bridging of the medial epicondyle fracture fragment with an area of interrupted periosteal reaction along the medial epicondyle(*arrows*). **b** By 10 weeks, an osseous tunnel has formed along the medial epicondyle (*arrow*) and, despite improved motor function (4/5 strength) of the flexor pollicis longus and flexor digitorum profundus to the index finger, the patient complained of persistent elbow stiffness with decreased range of motion in flexion–extension and persistent paresthesias in the median nerve distribution

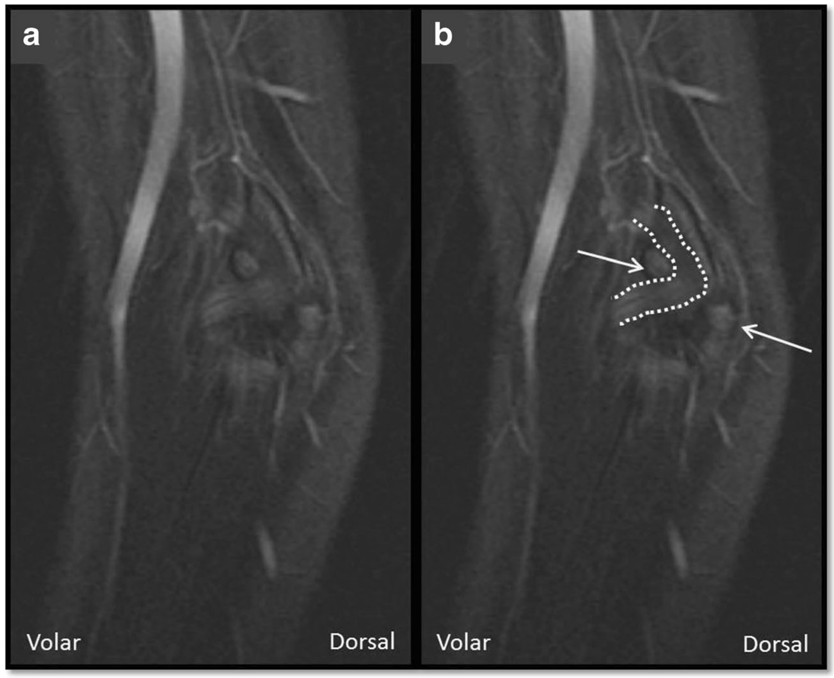

Fig. 3 **a** Sagittal inversion recovery image without annotations and with **b** annotations demonstrating an abnormal course of the median nerve, outlined by *dashed lines*, making an acute, hairpin turn as it passes through an osseous tunnel formed by abnormal healing of a medial epicondyle fracture fragment (*arrows*)

of the medial epicondyle was performed with release of the median nerve from the osseous tunnel. Comprehensive elbow capsular release was also performed to improve his decreased range of motion from post-traumatic arthrofibrosis.

During the operation, the median nerve was identified proximally and distally, and traced to an osseous tunnel between the medial epicondyle and the apophyseal fracture fragment (Fig. 9a). The immature bony callus was taken down, the medial epicondyle was mobilized, and the median nerve was freed from the osseous tunnel (Fig. 9b). To restore stability to the elbow, the medial epicondyle was reduced and fixed with a 4.0-mm cannulated screw. The wound was closed and the patient was placed in a soft dressing so that he could begin immediate physical therapy to increase his range of motion.

At his most recent post-operative follow-up visit, now 6 months after surgery, the patient had improved range of

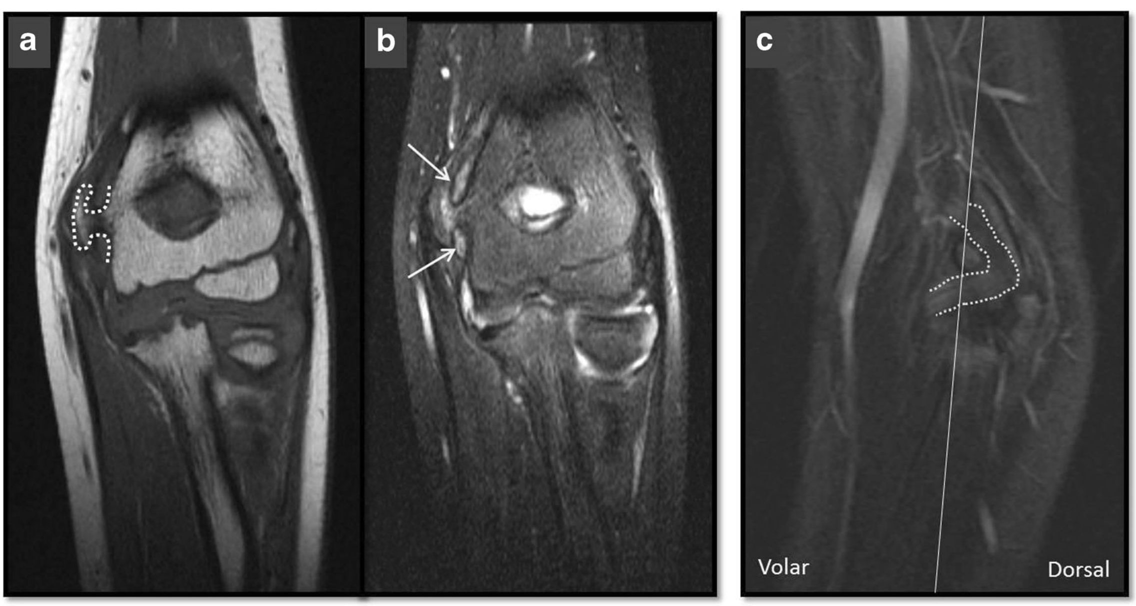

Fig. 4 **a** Coronal T1 and **b** coronal T2-weighted fat-saturated images corresponding with the position of **c** the vertical line on the sagittal image. The osseous bridging at the site of the medial epicondyle fracture fragment is well visualized on T1-weighted images (*dashed white line*) and the median nerve is well visualized on T2-weighted images (*arrows*), taking an acute turn as it courses through the osseous tunnel. On these images, the nerve is diffusely T2 hyperintense without focal nerve enlargement

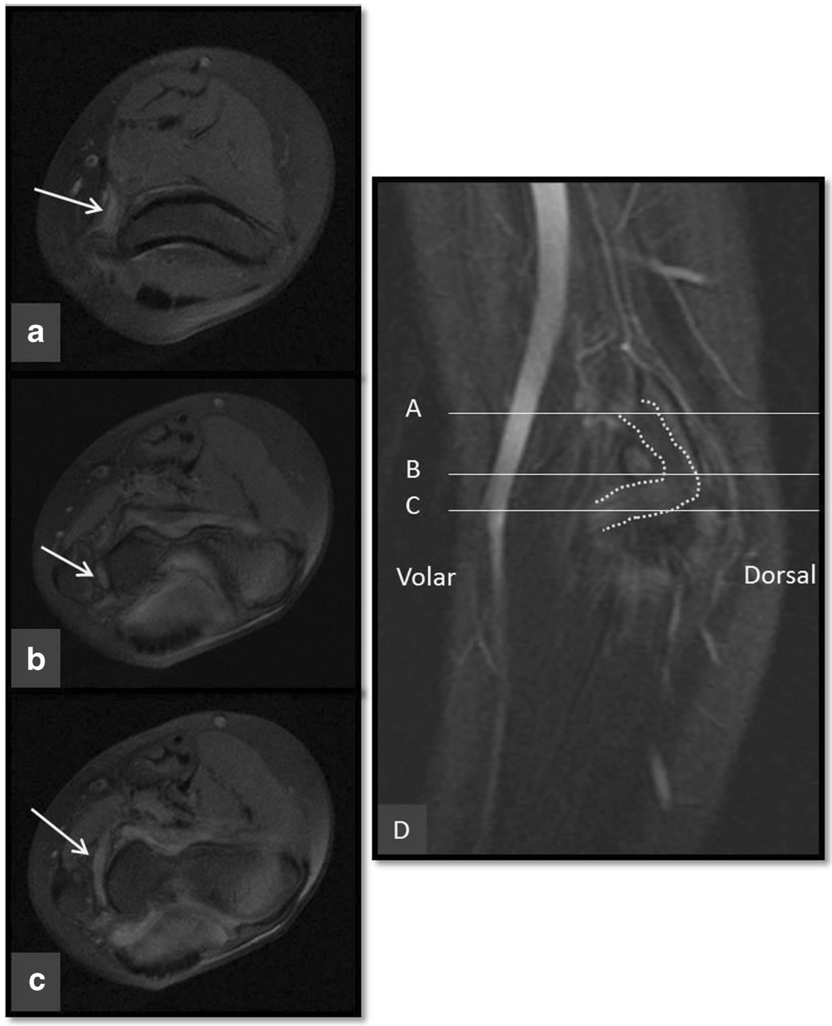

Fig. 5 **a–c** Axial proton density-weighted fat-saturated images from superior to inferior, corresponding with horizontal lines on **d** the sagittal image, demonstrate the abnormal course of the median nerve (*arrows*), coursing posteriorly into the osseous tunnel (*A*), within the tunnel (*B*), and making an acute anterior turn as it exits the tunnel distally (*C*). The typical fascicular morphology of the nerve was not well visualized on any MRI sequence as the nerve was oblique on all images. The ulnar nerve was not well visualized in the cubital tunnel secondary to a bulging joint effusion and posteromedial soft-tissue edema

motion with 5–95° of flexion–extension. The median nerve motor and sensory function had improved, with 4+/5 motor strength of the flexor pollicis longus and flexor digitorum profundus to the index finger and a normal sensory examination with no further paresthesias. He was actively working with an occupational therapist on regaining fine motor dexterity.

Discussion

Although medial epicondyle fractures are not uncommon in the setting of elbow dislocations, median nerve entrapment is an uncommon complication of elbow dislocation in the pediatric and young adult populations [7]. In this case, our patient sustained an ulnohumeral dislocation with simultaneous fracture of the medial epicondyle and traumatic median nerve injury with nerve entrapment in the healing medial epicondyle fracture, resulting in persistent neurological symptoms and elbow stiffness.

Median nerve entrapment was first described and classified by Fourrier et al. and Hallett, later expanded by Al-Qattan et al. [19–21]. Type 1 entrapment occurs when the median nerve is entrapped between the trochlea and the olecranon as a result of the avulsed medial epicondyle. Type 2 entrapment, seen in this case, occurs when the nerve is entrapped in the healed medial epicondyle fracture, but not within in the joint. Type 3 entrapment occurs when the nerve is kinked and entrapped within the joint between the distal humerus and the olecranon. Type 4 entrapment, added to the classification system only after surgical exploration revealed cases that did not fit into the three-tiered classification system previously described, occurs when the nerve is entrapped both in the healed fracture and within the joint. Type 4 entrapment is considered more severe than type 3 owing to double entrapment sites [20].

A detailed neurologic examination is critical following elbow dislocation and early imaging can provide valuable information about the presence, nature, and extent of nerve injury. In the setting of pediatric elbow dislocation associated with medial epicondyle fractures, radiographs are obtained first. Although

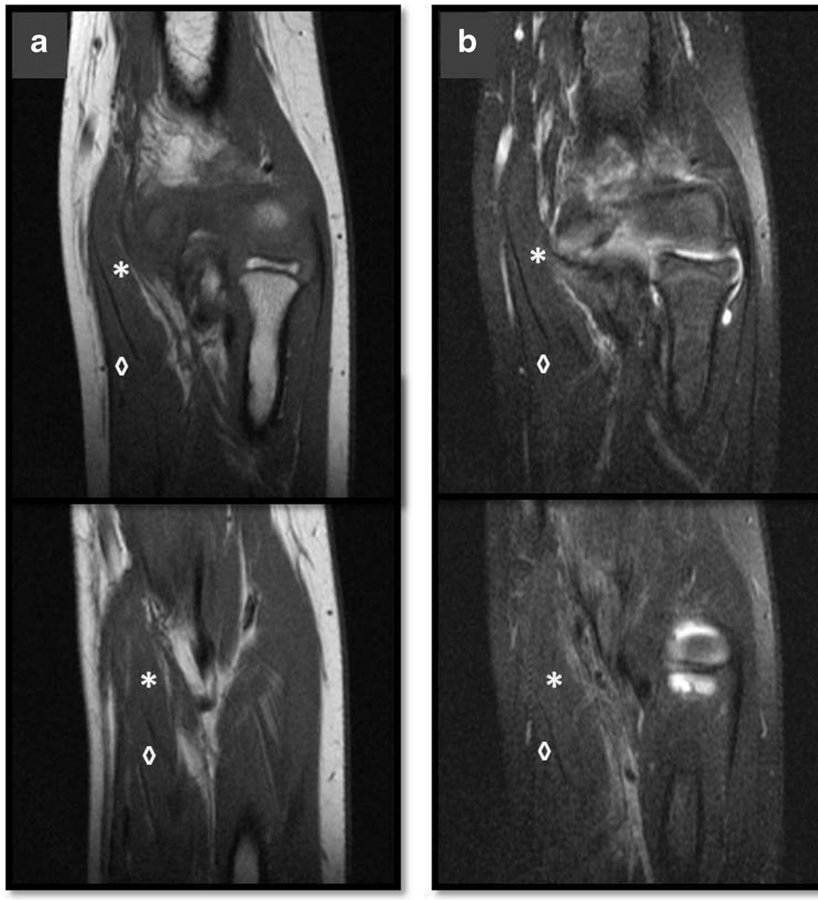

Fig. 6 **a** Sequential coronal T1-weighted and **b** coronal T2-weighted fat-saturated images of the volar forearm demonstrate normal morphology and signal intensity of the flexor carpi radialis muscle (*asterisk*) and palmaris longus muscle (*diamond*), both of which are supplied by the median nerve, without evidence for denervation-related atrophy on T1-weighted images or edema on T2-weighted images

radiographs evaluate the osseous structures well, they provide no information about nerve entrapment in the acute setting. One week following reduction, in-splint or cast X-rays are typically obtained to ensure the medial epicondyle fracture has not displaced further. At the time of splint/cast discontinuation, usually at around 3–5 weeks, radiographs are obtained to assess the extent of healing and alignment. Radiographs were obtained at these time intervals in our patient. In the setting of nerve entrapment, radiographs obtained at 6 weeks may demonstrate a "C" sign, resulting from an incomplete central circular defect within the medial epicondyle fracture callus that corresponds with the entrapped median nerve [22].

Following cast removal, patients with persistent stiffness are typically referred for physical therapy, with a follow-up orthopedic visit 3 months following injury. In the setting of nerve entrapment, if radiographs are repeated 3 months after injury, the Matev sign may be seen, described as two sclerotic lines in the posteromedial aspect of the distal humeral metaphysis on either side of a focally disrupted periosteal reaction at the site of median nerve entrapment [16, 23].

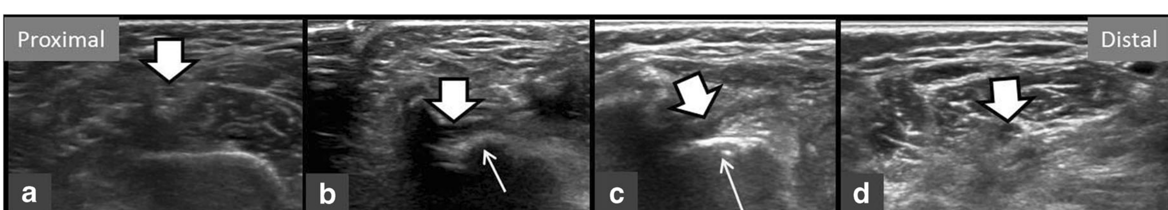

Fig. 7 **a** Grayscale short-axis ultrasound images of the median nerve (*large arrow*) in the distal upper arm, **b** as it enters the osseous tunnel, **c** as it exits the osseous tunnel, and **d** in the proximal forearm. Note that the medial epicondyle (*small arrow*) is seen on images (**b**, **c**). Although the nerve appeared normal in size, it appeared hypoechoic with fascicular prominence in the distal arm (**a**) and proximal forearm (**d**) and hypoechoic as it coursed through the osseous tunnel (**b**, **c**). Within the tunnel, the typical fascicular morphology of the nerve was not visualize, as the nerve was coursing obliquely and therefore not imaged in the true short-axis plane. The nerve is not visualized within the tunnel secondary to posterior acoustic shadowing from overlying bone

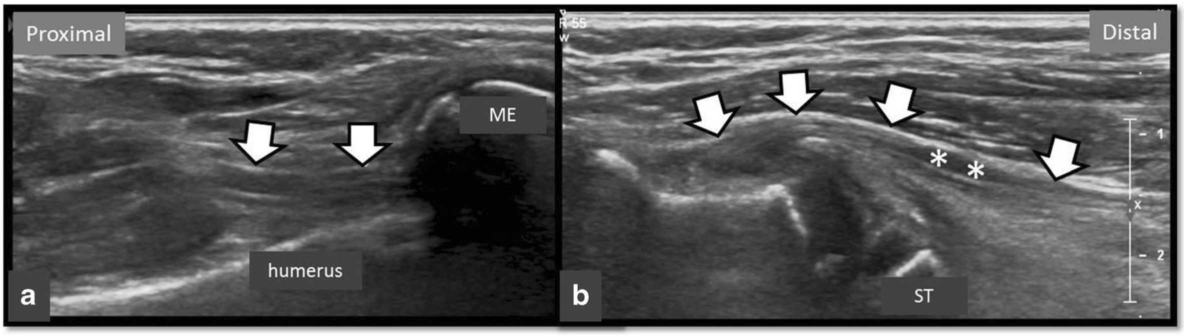

Fig. 8 Grayscale long-axis ultrasound images of the median nerve (*large arrows*) **a** proximal to and **b** distal to the avulsed medial epicondyle fragment demonstrate normal size, echogenicity, and fascicular morphology of the visualized median nerve through the site of entrapment with a focal hypoechoic area within the nerve more distally (*asterisks*) compatible with intraneural edema. A short segment of the median nerve was not visualized immediately deep to the fracture fragment secondary to posterior acoustic shadowing. *ME* medial epicondyle, *ST* sublime tubercle of the ulna

This was not demonstrated in our patient, however, as our patient had persistent neurological dysfunction and a limited range of motion at his 3-month follow-up appointment, and further work-up was warranted.

Although electrophysiological testing provides diagnostic information regarding nerve function, it is difficult to perform in children given its invasive nature. Instead, pediatric patients with persistent nerve palsies following trauma should undergo advanced imaging at the onset of neurological symptoms, with electrophysiological testing subsequently performed as needed.

Magnetic resonance imaging can distinguish normal from abnormal nerves based on size and signal intensity characteristics and can also demonstrate secondary findings of nerve damage, such as intramuscular edema and muscle atrophy in a specific nerve distribution [24]. Although these findings provide prognostic value, they are not always present in the early

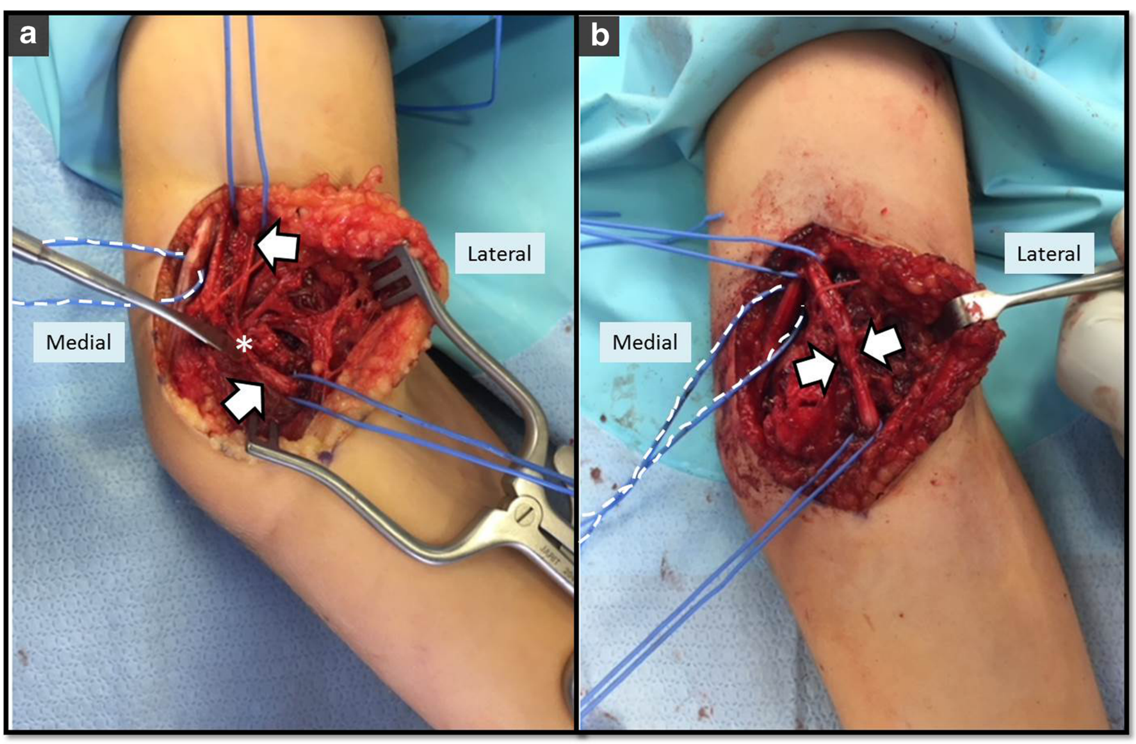

Fig. 9 Intraoperative photographs **a** before and **b** after mobilization of the medial epicondyle and release of the median nerve. On initial inspection (**a**), a portion of the median nerve was not visible, as it coursed deep to the surgical probe placed on the medial epicondyle fragment (*asterisk*), under which the median nerve (encircled by blue vessel loops and delineated by *large arrows*) was entrapped. The interrupted white vessel loop is around the ulnar nerve. Following mobilization of the medial epicondyle (**b**), the median nerve is in continuity (encircled by solid blue vessel loops and delineated by *large arrows*); however, it is distorted and kinked at the site of entrapment. The interrupted white vessel loop is around the ulnar nerve

post-traumatic period. Furthermore, post-traumatic soft-tissue edema, fracture or hematoma immediately following an injury may obscure detailed imaging of small peripheral nerves on MRI. Ultrasound has excellent spatial resolution and is being increasingly used for peripheral nerve imaging. Ultrasound can assess the size, echogenicity, and fascicular morphology of nerves and can identify adjacent soft-tissue or osseous compression lesions. For these reasons, in addition to its dynamic imaging capabilities, ability to compare with the contralateral side, long segment assessment of nerves in the extremities, low cost, and increasing accessibility, ultrasound may be the ideal first imaging option for suspected peripheral neuropathy [25, 26].

Entrapment of the median nerve in a healing medial epicondyle fracture is a rare but serious potential complication of an elbow dislocation. In all cases of entrapment, early diagnosis and treatment led to improved outcomes [15]. If the diagnosis of nerve entrapment is made early, mobilization of the nerve can be performed with good outcomes, as seen in our case. If the diagnosis is delayed, treatment typically involves resection of the damaged nerve segment with re-anastomosis with or without grafting [11]. In these cases, full recovery is not expected. Given the poor outcomes associated with delayed diagnosis of median nerve entrapment after medial epicondyle fracture, imaging should be obtained promptly when neuropathic symptoms persist. Although both MRI and ultrasound are capable of imaging peripheral nerves, ultrasound may be the best first option given its availability, excellent spatial resolution, and, as demonstrated here, accuracy in diagnosing peripheral nerve entrapment.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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