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Optimal examination for traumatic nerve/muscle injuries in earthquake survivors: a retrospective observational study

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Background: Physiatrists are facing with survivors from disasters in both the acute and chronic phases of muscle and nerve injuries. Similar to many other clinical conditions, neuromusculoskeletal ultrasound can play a key role in the management of such cases (with various muscle/nerve injuries) as well. Accordingly, in this article, a recent single-center experience after the Turkey-Syria earthquake will be rendered.
Methods: Ultrasound examinations were performed for various nerve/muscle lesions in 52 earthquake victims referred from different cities. Demographic features, type of injuries, and applied treatment procedures as well as detailed ultrasonographic findings are illustrated.
Results: Of the 52 patients, 19 had incomplete peripheral nerve lesions of the brachial plexus (n = 4), lumbosacral plexus (n = 1), and upper and lower limbs (n = 14).
Conclusion: The ultrasonographic approach during disaster relief is paramount as regards subacute and chronic phases of rehabilitation. Considering technological advances (e.g., portable machines), the use of on-site ultrasound examination in the (very) early phases of disaster response also needs to be on the agenda of medical personnel.

Keywords: Disasters; Entrapment; Neuropathy; Sono-Tinel; Ultrasonography

Introduction

Natural disasters are unexpected occurrences that can result in destruction and heavy casualties [1,2], and earthquakes are likely to have the greatest negative impact on human health among them. Growing populations have increased the need for living spaces, especially in cities, thereby putting individuals in a riskier position against earthquakes in developing countries. On February 6, 2023, two earthquakes (moment magnitudes of 7.8 and 7.6) with a 9-hour interval struck southern Turkey and western Syria. At present, they are the strongest "doublet" earthquakes ever recorded in the Levant [3]. The impact on mortality (fifth deadliest of the 21st century) and costs (fourth costliest) was catastrophic [4]. As an interesting side note, the occurrence of these earthquakes in this region is also believed to be a sign of the apocalypse. Likewise, the great battle (Armageddon) is also expected to take place in this zone.

From a medical perspective, physicians need to tackle various neuromusculoskeletal conditions and their complications (e.g.,

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fracture, crush injury, amputation, compartment syndrome, and nerve lesions) after earthquakes. In addition to the well-established role of physiatrists in the long-term rehabilitation of pertinent cases, the medical services provided to these patients can notably be upgraded with the prompt and convenient use of ultrasound (US) examination. US can play a key role in diagnosing soft tissue and peripheral nerve lesions in posttraumatic conditions. Some exemplary findings would include focal nerve/fascicular enlargement, loss of internal fascicular structure, nerve discontinuity, and increased cross-sectional area of the nerve in nerve injuries [5]. Traumatic muscles can show signs of swelling with or without focal/general areas of increased echogenicity (muscle strain), hypo/hyperechogenic appearance with or without fibrillar discontinuity (muscle contusion), hypoechoic or anechoic circumscribed lesions (muscle hematoma), and muscle atrophy [6,7]. Sono-Tinel, a probe compression that causes pain on the pathological side, is also suggestive of these lesions [8]. To this end, also being aware of the mounting utility of US in physiatry, we considered that a pictorial essay summarizing our recent experience with the Kahramanmaraş earthquake would help to exemplify its actual contribution to disaster relief. In particular, we tried to render how US examination impacted our medical approach to nerve/muscle injuries.

Methods

Ethical statements: Patient consent was obtained from the patients before the physical examination. An approval from the Institutional Review Board was waived due to the retrospective nature of the study.

Hacettepe University Hospital is a tertiary referral center that has treated earthquake survivors. A total of 52 individuals— who were consulted from different in-patient services or who applied to our outpatient clinic—were examined. Table 1 summarizes the clinical features and treatment methods used. Earthquake survivors who had been examined in our department between February 13, 2023 and April 4, 2023 were included, and pertinent data were collected between April 5, 2023 and April 29, 2023.

After a complete physical examination (orthopedic examination of all involved joints and their adjacent joints and neurological examination including muscle strength, light touch sensation, pain sensation, deep tendon reflexes, and pathological reflex examinations), all patients were also evaluated for various nerve/muscle injuries by US examination. Six patients were scanned using a 5 to 12 MHz linear transducer (GE Logiq P5, Madison, WI, USA), and a portable device with a linear transducer (4–13 MHz, Clarius L7; Clarius Mobile Health, Vancouver, BC, Canada) was used for the remaining cases.

Results

The mean age of the patients was 29.4 ± 19.4 years (range, 7–72 years). The mean duration of being trapped under rubble was 28.6 ± 30.4 hours (range, 4–120 hours). Nineteen patients had peripheral nerve involvement, including four brachial plexuses, one lumbosacral plexus, and 17 limb nerve injuries (the peroneal nerve being the most affected) (Table 1). The characteristic ultrasonographic findings of earthquake victims with nerve/muscle injuries are summarized in Table 2. Electrodiagnostic studies were not performed because the patients had skin lesions such as abrasion and edema or were bandaged. Magnetic resonance imaging (MRI)

Table 1. Patient list of earthquake victims at he Department of Physical Medicine and Rehabilitation, Hacettepe University Medical School in 2023

Age (yr)	Sex	City	Duration (hr)	Affected body part	Nerve injury	Amputation	Fasciotomy	Treatment
28	F	Hatay	12	Right LE	-	-	Right tibia	Exercise
16	F	Adıiyaman	62	Right UE, left LE	-	Right transhumeral, left transfemoral	-	Exercise
13	F	Hatay	48	Left LE	-	Left transtibial	-	Exercise
48	M	Malatya	24	Bilateral LE	-	-	Bilateral tibia	Exercise
8	F	Hatay	35	Bilateral LE	Right peroneal	Left transfemoral	Right tibia	Exercise, bandaging
63	F	Hatay	32	Vertebra	-	-	-	Exercise
52	F	Gaziantep	4	Right LE	-	-	Right tibia	Exercise
33	F	Adiyaman	6	Right UE, left LE	Right radial	-	-	Exercise, ES, splint
55	M	Adiyaman	Unknown	Cranium	-	-	-	Exercise
18	F	Adiyaman	8	Vertebra, pelvis	-	-	-	Exercise
71	F	Hatay	30	Bilateral LE	-	-	-	Exercise
62	F	Adiyaman	6	Vertebra	-	-	-	Exercise
16	F	Hatay	80	Bilateral UE	Left ulnar	Right transhumeral	-	Exercise

(Continued to the next page)

Table 1. Continued

Age (yr)	Sex	City	Duration (hr)	Affected body part	Nerve injury	Amputation	Fasciotomy	Treatment
17	F	Adana	9	Right UE	Right radial	-	-	Exercise, FES
46	F	Hatay	96	Right UE	Right radial	-	-	Exercise, FES
37	F	Unknown	Unknown	Right UE, left LE	Right radial	-	-	Exercise, ES, splint
19	M	Unknown	6	Bilateral LE	-	-	-	Exercise
5	F	Hatay	120	Bilateral UE, bilateral LE	Right brachial plexus	-	Bilateral tibia	Surgery
17	F	Hatay	8	Right LE	-	-	Right femur	Exercise
7	M	Adiyaman	3	Right LE, left UE	-	Left hand 3rd finger	-	Exercise
16	F	Hatay	40	Bilateral LE	-	Left foot 2nd, 3rd, 4th toes	Right tibia	Exercise, FES
10	M	Kahramanmaraş	5	Right LE	-	-	Right tibia	Exercise
8	F	Kahramanmaraş	20	Bilateral LE	-	-	Bilateral tibia	Exercise
15	M	Hatay	Unknown	Left UE, pelvis	Bilateral lumbosacral plexus	Left transradial	-	Exercise
53	F	Adiyaman	56	Right UE, left LE	Right median, ulnar, PIN, SRN	Left transfemoral	-	Exercise
13	F	Hatay	6	Bilateral LE	-	-	Bilateral femur	Exercise, FES, splint
38	F	Hatay	48	Bilateral LE	-	-	-	Exercise
16	M	Hatay	5	Bilateral LE	-	-	Bilateral tibia	Exercise, gabapentin
12	F	Hatay	Unknown	Vertebra	-	-	-	Exercise
11	M	Hatay	Unknown	Cranium, vertebra, pelvis	-	-	-	Exercise
15	M	Hatay	7	Left LE	-	-	-	Exercise, cold pack
17	M	Hatay	7	Right LE	-	-	Right tibia	Exercise, splint
20	M	Hatay	6	Bilateral LE, right UE	-	-	Right femur, bilateral tibia	Exercise, splint
51	F	Hatay	32	Bilateral UE	Left brachial plexus	-	Right humerus	Exercise, FES
9	M	Hatay	Unknown	Cranium, left UE	-	-	Left radius-ulna	Exercise, facial massage
20	M	Hatay	8	Bilateral LE	-	-	Right femur, bilateral tibia	Exercise
18	M	Hatay	18	Bilateral LE	-	Bilateral transfemoral	-	Exercise
45	M	Hatay	5	Vertebra, pelvis	-	-	-	Exercise, splint
46	F	Hatay	96	Right UE	Right C5, radial, PIN	-	-	Exercise, ES, splint
18	M	Hatay	36	Bilateral LE	Bilateral sciatic	-	-	Exercise, splint, FES
44	F	Hatay	12	Left LE	Left sciatic, peroneal	-	-	Exercise, splint, FES, contrast bath
24	F	Hatay	45	Bilateral LE	Left sciatic, peroneal	Right transfemoral amputation	-	Exercise, splint
65	F	Hatay	48	Bilateral LE	Bilateral peroneal	-	-	Exercise, splint
10	M	Hatay	6	Right LE	-	-	-	Exercise
65	F	Hatay	4	Left UE, pelvis	Left brachial plexus	-	-	Exercise
28	F	Hatay	43	Left LE	Left sciatic	-	-	Exercise
16	M	Hatay	Unknown	Bilateral LE	-	-	Left tibia	Exercise, splint
43	F	Hatay	8	Left UE, left LE	-	-	-	Exercise, cold pack, TENS
36	M	Hatay	26	Left LE	-	-	Left tibia	Exercise, splint
72	F	Hatay	12	Right LE	-	-	-	-
32	M	Hatay	120	Left LE	Left sciatic, peroneal	-	-	Exercise, splint, FES
13	F	Hatay	72	Right LE	Right peroneal	-	-	Exercise

F, female; M, male; LE, lower extremity; UE, upper extremity; ES, electrical stimulation; FES, functional electrical stimulation; PIN, posterior interosseous nerve; SRN, superficial radial nerve; TENS, transcutaneous electrical nerve stimulation.

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Table 2. Characteristic ultrasonographic findings of earthquake victims with nerve/muscle injury

Site	Finding
Nerve	Increased cross-sectional area
	Fascicular edema
	Nerve compression
	Focal nerve enlargement
	Plexopathy
Muscle	Muscle strain
	Muscle contusion
	Muscle hematoma

for plexopathy was performed in five patients. The remaining patients were diagnosed with peripheral nerve entrapment based on physical and ultrasonographic examinations. Of the 52 patients, six who had demonstrative/exemplary imaging findings were selected for this study. They are further discussed in detail, with a special focus on the US findings.

1. Case 1

A 53-year-old female with left transfemoral amputation. She was trapped under rubble for 56 hours, and her leg was pinned under a steel door. Although she had no motor deficits, she had sensory loss on the dorsal side of her right hand and hypoesthesia in all fingers (median greater than the ulnar side). She had also multiple abrasions on her right forehand. US examination of the forearm/elbow revealed dermal/subcutaneous edema and heterogeneous hypo/hyperechoic flexor muscles. US also showed a swollen posterior interosseous nerve (PIN) with proximal and distal compression sites and a swollen median nerve in the mid-forearm. The superficial radial nerve (SRN) was edematous, particularly underneath the scarred area (Figs. 1, 2; Supplementary Videos 1–5). Based on the physical and US examinations, the patient was diagnosed with median, PIN, and SRN neuropathies.

2. Case 2

A 51-year-old female with right transhumeral amputation. She was trapped under rubble for 32 hours. Physical examination revealed weak left shoulder abductors, elbow flexors, and extensors (1+/5, 0/5, and 2/5, respectively). Wrist flexors, extensors, and hand intrinsic muscles were also weak on the left side (4–/5). She described hypoesthesia on an area innervated by the C5 nerve root. Deep tendon reflexes were negative. US examination of the brachial plexus at the interscalene region revealed swollen nerve roots (especially C5) compared with the normal side (Fig. 3). MRI of the brachial plexus was compatible with C5 to C7 nerve root involvement. Based on the physical examination and imaging findings, the patient was diagnosed with brachial plexopathy.

Fig. 1. The patient had healing wound areas on (A) the medial and (B) flexor sides of the right forearm, as well as the dorsum of the hand.

3. Case 3

A 33-year-old female with wrist drop. She was trapped under rubble for 6 hours. She also had a talus fracture. On physical examination, the wrist and finger extensors were weak (3–/5 and 1/5, respectively) and the rest of the neurological examination was normal. US examination of the distal arm and proximal forearm depicted an edematous radial nerve and PIN (Fig. 4, Supplementary Video 6). The patient was diagnosed with radial nerve and PIN involvement based on the physical examination and US findings.

4. Case 4

A 15-year-old male with a painful left hip/leg. He was trapped under rubble for 6 hours. Due to severe hip pain, he tended to keep his left leg always in the same position (i.e., flexion, abduction, and external rotation). On physical examination, hip adduction and internal rotation were limited. His left leg was also painful upon palpation. Neurological examinations were otherwise noncontributory. US examination of the anterior hip region revealed a hematoma

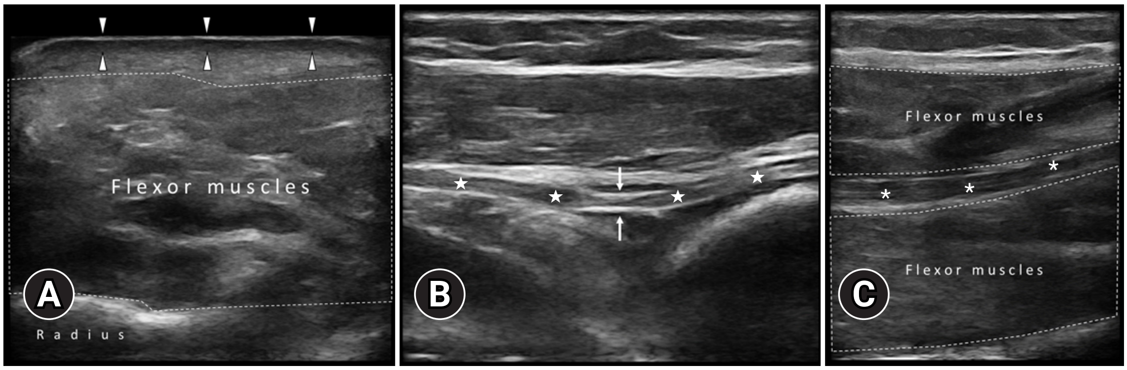

Fig. 2. (A) Ultrasonographic image shows the dermal/subcutaneous edema (double arrow) and flexor muscles with heterogenous hypo/hyperechoic appearance (dashed area). (B) Long-axis imaging of the forearm illustrates the edematous posterior interosseous nerve (stars) proximal and distal to the compression site (thin arrows). (C) Long-axis imaging also demonstrates the swollen median nerve (asterisks) passing through the heterogenous hypo/hyperechoic flexor muscles (dashed areas).

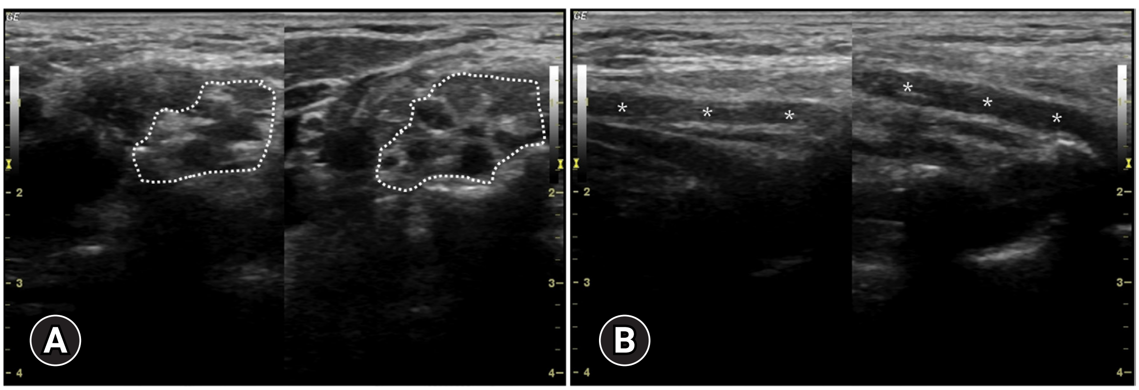

Fig. 3. (A) Short-axis ultrasound examination of the brachial plexus (dashed area) at the interscalene region shows swollen nerves (right image) in comparison to the normal side (left image). (B) Long-axis view of the C5 nerve root (asterisks) proximally also shows edema on the involved side (right image) in comparison to the normal side (left image).

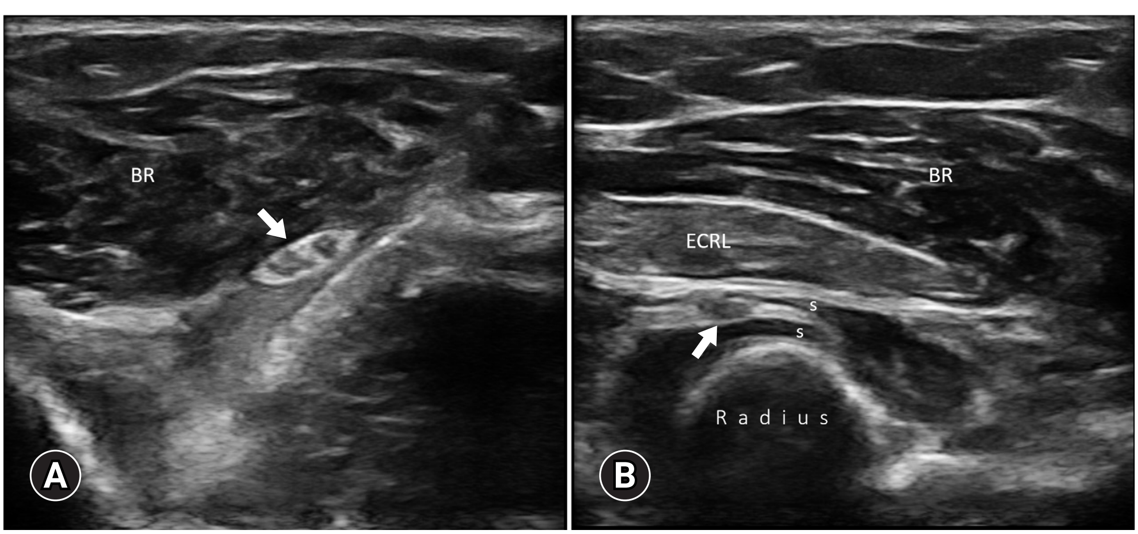

Fig. 4. Short-axis images of (A) the distal arm and (B) proximal forearm depict the swollen radial (arrow) and posterior interosseous (arrow) nerves. BR, brachioradialis; ECRL, extensor carpi radialis longus; S, supinator muscle.

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in the iliopsoas muscle. The dermis, subcutaneous fat, rectus femoris, and vastus intermedius muscles were swollen in the left thigh (Fig. 5, Supplementary Videos 7–10). These findings were consistent with early strain in the anterior thigh muscles.

5. Case 5

A 16-year-old female with right transhumeral amputation. She was trapped under rubble for 80 hours. On inspection, she had a claw hand on her left side. The 3rd and 4th lumbrical muscle strength was 2/5, and the abductor digiti minimi muscle strength was 1/5. She had hypoesthesia in her 4th and 5th fingers. The rest of the neurological examination was unremarkable. US examination showed an edematous ulnar nerve passing through Guyon's canal (Fig. 6). Based on the physical and US examinations, the patient was diagnosed with ulnar neuropathy. Supplementary Video 11 shows an edematous ulnar nerve in another patient.

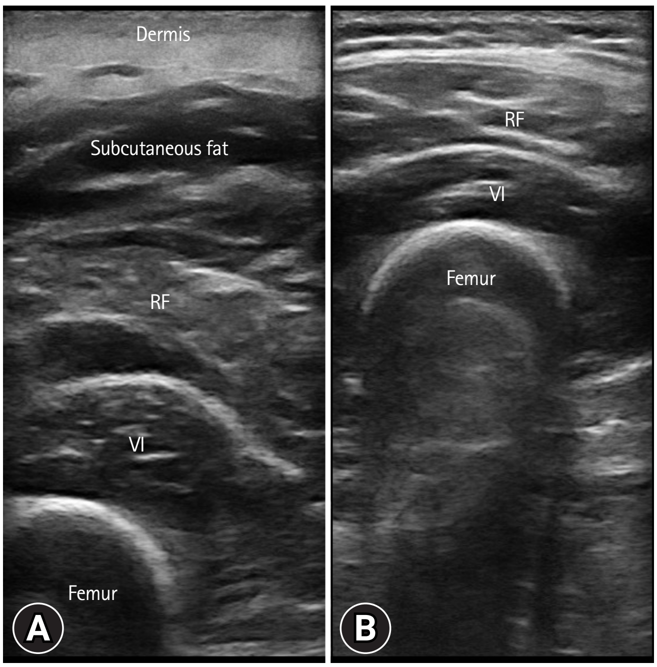

Fig. 5. (A) Comparative ultrasound imaging over the anterior thigh shows swollen dermis, subcutaneous fat, rectus femoris (RF), and vastus intermedius (VI) muscles on the involved side. (B) Normal side.

6. Case 6

An 18-year-old male with bilateral foot drop. He was trapped under rubble for 36 hours. On physical examination, foot dorsiflexors and plantar flexors were weak (0/5) on both sides. He also described hypoesthesia on the dorsal/plantar side of the right foot. US examination revealed fascicular edema in both sciatic nerves (Fig. 7, Supplementary Video 12). Based on physical and US examinations, the patient was diagnosed with bilateral sciatic neuropathy. Supplementary Videos 13 and 14 show swollen peroneal nerves in another patient with a similar history.

Discussion

US is a simple, fast, and inexpensive examination method that plays an important role in the management of traumatic peripheral nerve/muscle injuries [9,10]. Owing to its portability, not only in routine daily practice but also in several settings can it be applied in a convenient/effective way. Following our recent experience, we actually aim to extend the possibility—also to include its use " on-

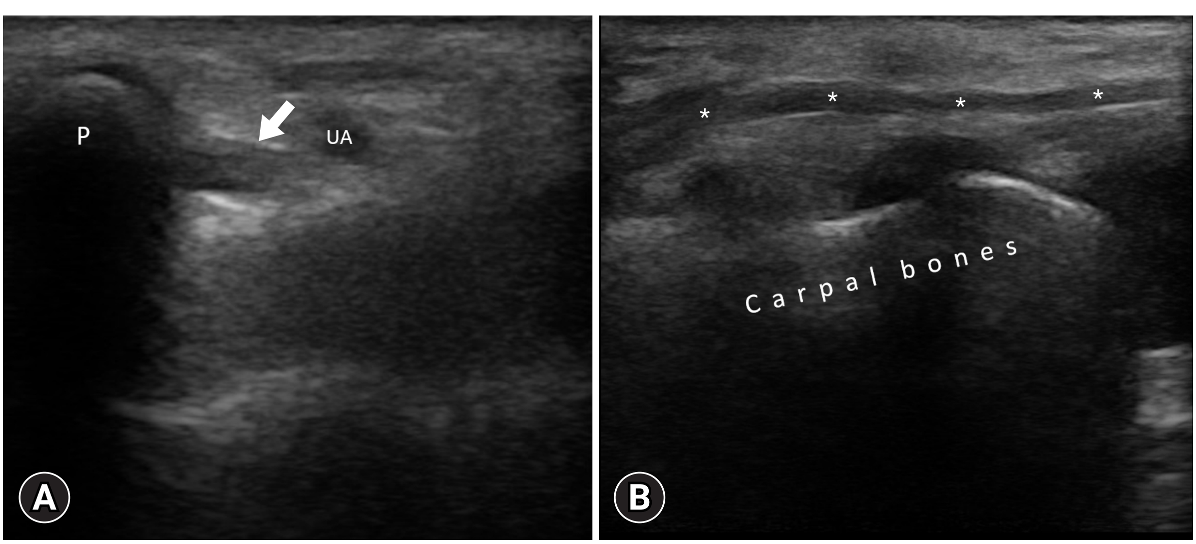

Fig. 6. (A) Axial and (B) longitudinal ultrasonographic images demonstrate the edematous ulnar nerve (arrow and asterisks) passing through Guyon's canal. UA, ulnar artery; P, pisiform bone.

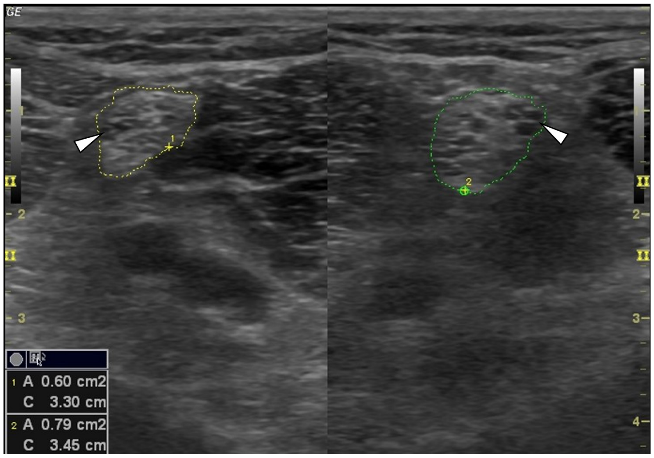

Fig. 7. In addition to fascicular edema (arrowheads), cross-sectional area measurements also confirm that the sciatic nerve is swollen (0.79 cm^2 vs. 0.60 cm^2).

site." In other words, physiatrists/physicians would be capable of contributing to the prompt triage of these patients. Needless to say, the spectrum of emergency pathologies that can be examined with US also comprises those of the cortical bone. As such, occult fractures can also be diagnosed simultaneously. Indeed, these fractures may be associated with lesions in the surrounding peripheral nerves or soft tissues/muscles. Discontinuity of the hyperechoic cortical bone and hypoechoic subperiosteal hematoma are the major US findings in bone fractures in the acute phase [11].

Peripheral nerves can be injured by mechanical compression, ischemia, or direct trauma [12]. While the diagnosis can already be challenging enough in daily routine, an earthquake scenario definitely adds up to the difficulty of diagnosis. Yet, the complexity of the trauma (compartment syndrome, fasciotomy, fractures, amputation, etc.) and the accompanying medical conditions would contribute to this aspect. Additionally, electrodiagnosis is either impossible or has limited use in these patients. Of note, the other (magnetic resonance) imaging option is again not applicable for several simple reasons. On the contrary, the flexible use of the US transducer provides access to different regions regardless of the patient's position/condition. Scanning throughout their entire course, peripheral nerves as well as the pertinent muscles can be examined both statically and dynamically, where appropriate. Nerve integrity, edema, partial/complete rupture, and the underlying cause of injury are examined in a comprehensive approach. In the management of earthquake survivors, US plays a paramount role in ensuring early and accurate diagnosis, facilitating the timely initiation of appropriate rehabilitation program, it encompasses a spectrum of interventions, including range of motion, strengthening and mobilization exercises where applicable, functional electrical stimulation of denervated muscles, orthoses/splints, prosthetic programs for patients with amputated limbs, and various physical therapy modalities for pain control [13]. US will also assist in the prompt implementation of tailored rehabilitation plans during follow-up. It is noteworthy that the patient-friendly nature of US indisputably helps the physician and the "already traumatized" patient alike. After precise diagnoses, physical therapy, interventions, or surgery can timely be applied. Lastly, US will also aid in closely monitoring the morphological changes during healing/treatment.

Supplementary materials

Supplementary Videos 1–14 can be found via https://doi.org/10.12701/jyms.2024.00087.

Article information

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

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