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ORIGINAL ARTICLE

Clinical, etiological, and electrophysiological characteristics of patients with peripheral nerve damage caused by the February 6 earthquake in Türkiye

Tulin Gesoglu Demir[1], **Kadri Burak Ethemoglu**[2]

[1]Department of Neurology, Harran University Faculty of Medicine, Şanlıurfa, Türkiye
[2]Department of Neurosurgery, Metrolife Hospital, Şanlıurfa, Türkiye

ABSTRACT

Objectives: This study aimed to analyze the clinical, etiological, and electrophysiological characteristics of the February 6 earthquake victims referred to our center due to nerve damage.

Patients and methods: In this retrospective study, the demographic characteristics and findings of clinical examinations of 36 earthquake victims (25 females, 11 males; mean age: 31.6±15.5 years; range, 5 to 61 years) referred to our electrophysiology laboratory during the four-month period following the February 6 earthquake were investigated. The patients' time spent under rubble, affected extremities, and electrophysiological findings were evaluated, and the locations of their lesions were determined using electromyography.

Results: The mean time spent under rubble was 14.94±18.62 h, and 31 (86.1%) patients experienced partial nerve damage. Nerves were affected peripherally in 23 (74.2%) patients, at the lumbosacral plexus level in four (12.9%) patients, and at the brachial plexus level in another four (12.9%). Patients who were under rubble for more than 6.5 h had an increased risk of developing crush syndrome (p=0.014), and those under rubble for more than 8.5 h had an increased risk of developing compartment syndrome (p=0.008).

Conclusion: The duration of exposure to rubble has been identified as a significant factor in the severity of nerve injury, as well as the development of compartment syndrome and crush syndrome. Therefore, the potential for peripheral nerve injury, which is a significant cause of morbidity, should be considered in the follow-up of patients who have survived earthquakes.

Keywords: Earthquake, electromyography, peripheral nerve damage.

In the early morning of February 6, 2023, an earthquake with a magnitude of 7.8 on the Richter scale (Mw) devastated central, southern, and southeastern Türkiye, as well as northwestern Syria. With an epicenter in Kahramanmaraş province, the quake affected 10 provinces with a total population of 15 million. Nine hours later, a second earthquake with a magnitude of 7.7 Mw struck 95 km northeast of Kahramanmaraş province, which only amplified the effects of the first earthquake.[1] Together, the earthquakes not only caused approximately 20,000 buildings to collapse and damaged more than 200,000 others[2] but were soon also described as the disaster of the century due to the number of deaths and the extent of material losses.[1]

Recent research has shown that with population growth and increased urbanization,[3] societies worldwide have become more vulnerable to injuries and death from large earthquakes in the past 50 years.[4] Because earthquake-related injuries usually result from falling objects or tissue compression over extended periods,[5] the epidemiology of earthquake-related injuries and deaths differs from that of other disasters. Therefore,

Correspondence: Tulin Gesoglu Demir, MD. Harran Üniversitesi Tıp Fakültesi, Nöroloji Anabilim Dalı, 63290 Haliliye, Şanlıurfa, Türkiye.
E-mail: drtulindemir@gmail.com

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robust and easily accessible local health services that can respond to such injuries are imperative.[6]

Despite studies on earthquake-related injuries such as crush syndrome, fractures, infections, and rhabdomyolysis,[7-9] the literature on earthquake-related peripheral nerve damage remains rather limited.[10,11] However, studies investigating nerve injuries resulting from earthquakes concluded that peripheral nerve injuries are common in disasters such as earthquakes.[10-12] Other research revealed that traumatic peripheral nerve injuries can cause severe disability and thus present a significant problem for public health[13] and that nerve damage significantly impacts function and employment, thereby resulting in significant healthcare costs.[14] However, because peripheral nerve injuries are not life-threatening, the partial and permanent disabilities that they cause following earthquakes may be neglected compared to the immediately devastating effects of the disasters. Even so, peripheral nerve injuries can affect quality of life in the long term. Hence, this study aimed to analyze the clinical, etiological, and electrophysiological characteristics of earthquake victims referred to our center due to peripheral nerve damage.

PATIENTS AND METHODS

This retrospective study examined earthquake victims with complaints of motor weakness, sensory loss, paresthesia, or pain who were referred from various clinics to the electrophysiology laboratory at the Harran University Faculty of Medicine between February 2023 and May 2023. Ultimately, our sample included 36 patients (25 females, 11 males; mean age: 31.6±15.5 years; range, 5 to 61 years) with peripheral nerve injuries according to the findings of electromyography (EMG). The patients' demographic data, findings from neurological examinations, detailed trauma history, and clinical presence of fracture, amputation, widespread soft tissue damage, compartment syndrome, and crush syndrome were recorded. In neurological examinations, muscle strength, sensory perception, and deep tendon reflexes were evaluated as well.

The time that the patients remained under rubble following the earthquake was recorded, and their affected extremities and electrophysiological findings were also evaluated. Nerve conduction studies and needle EMGs were performed to determine both the localization of the lesions for the spinal cord root, nerve plexus, and peripheral nerves and the extremity or extremities and the number of nerves affected. Peripheral nerve damage was classified as either complete or partial axon damage depending on the time elapsed until EMG. Electromyography was performed by a single doctor using the same EMG device (Keypoint version 2.38; Medtronic Dantec, Skovlunde, Denmark) and the same protocols.

Patients without any history of being trapped under rubble and those who could not undergo EMG or who could not be examined due to open wounds or amputation, among other conditions, were excluded from the sample.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). After the data of the patients were documented, the distribution of the data was evaluated according to the Kolmogorov-Smirnov and Shapiro-Wilk normality test. Mann-Whitney U test was used for non-normally distributed variables. Independent Sample t-test was used for comparison of normally distributed variables. ROC analysis was performed to determine the diagnostic value of the variables. The relationship between variables was evaluated by correlation (Pearson, Spearman's and Kendall's Tau) analysis. Frequency analysis of variables was performed by Cross-Tabulation and Frequency analysis. A p value of <0.05 was accepted as statistical significance in all tests.

RESULTS

The mean time for patients to apply to the EMG unit was 39.33±18.55 days (range, 20 to 86 days). Control EMG could be performed in five (13.9%) patients. Although these patients were pulled out from under rubble, none of them exhibited any peripheral nerve damage.

Of the 31 patients with peripheral nerve damage, four (12.9%) had lumbosacral plexus damage, four others had brachial plexus damage, and the remaining 23 (74.2%) had distal peripheral nerve damage in their extremities. Table 1 shows the clinical, demographic, and EMG characteristics of those patients. Upper extremities were unilaterally affected in 12 (38.7%) patients, whereas lower extremities were affected in 19 (61.3%) patients (bilaterally in four and unilaterally in 15). Of the patients with peripheral nerve damage, one nerve was affected in 14 (45.1%) patients, two nerves were affected in seven (22.5%) patients, three nerves were affected in one (3.2%) patient, and four or more nerves were affected in nine (29.0%) patients.

TABLE 1
Demographic and clinical characteristics of the patient group (n=36)

	n	%	Mean±SD
Age (year)			31.6±15.5
Sex			
Male	11	30.6	
Female	25	69.4	
Time under rubble (h)			14.94±18.62
Time until EMG procedure (day)			39.33±18.55
Crush syndrome	22	61.1	
Compartment syndrome	7	19.4	
Nerve injury	31	86.1	
Upper extremity	12	38.7	
Lower extremity	19	61.3	
Nerve injury localization			
Peripheral nerve	23	74.2	
Brachial plexus	4	12.9	
Lumbosacral plexus	4	12.9	

SD: Standard deviation; EMG: Electromyography.

Regarding the distribution of affected nerves among the patients with peripheral nerve damage, the sciatic nerve (n=11, 30.6%) was the most affected nerve, followed by the peroneal nerve (n=9, 25%) and radial nerve (n=8, 22.2%). Median and ulnar nerves (n=7, 19.4%) were damaged nearly as frequently. According to EMGs, all patients showed partial axonal degeneration (Figure 1).

Control EMG was performed in five patients in the six weeks to three months following the earthquake. In all five patients, reinnervation potentials and increased motor unit recruitment were detected. Their data were subsequently sorted according to the time when EMGs were performed. In the first patient, whose control EMG was performed six weeks after the earthquake and

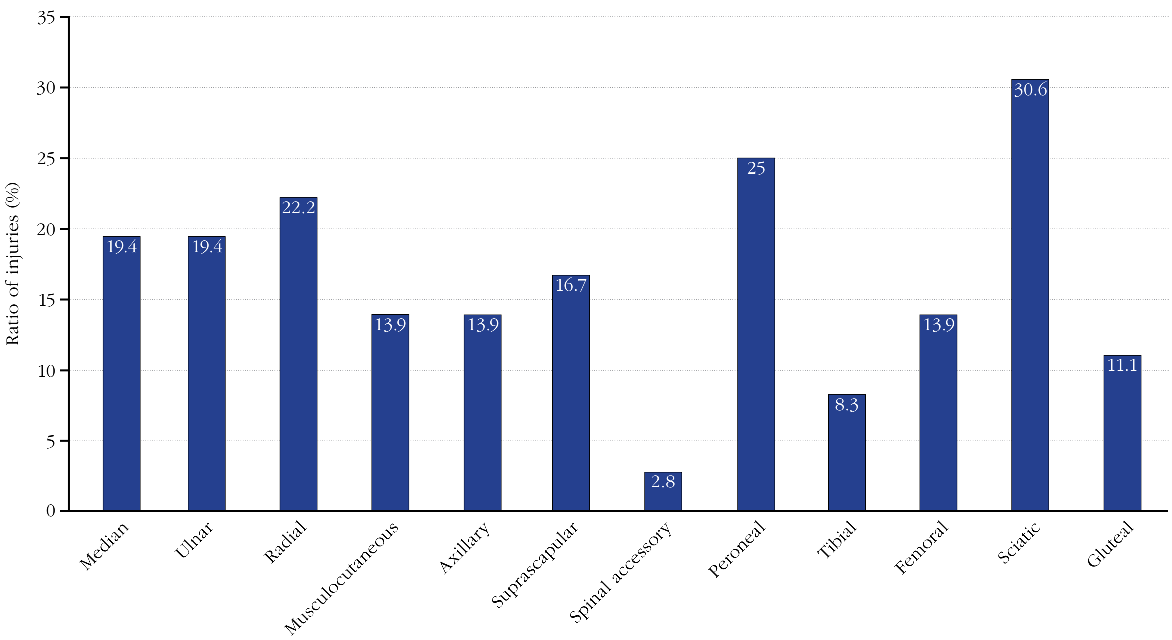
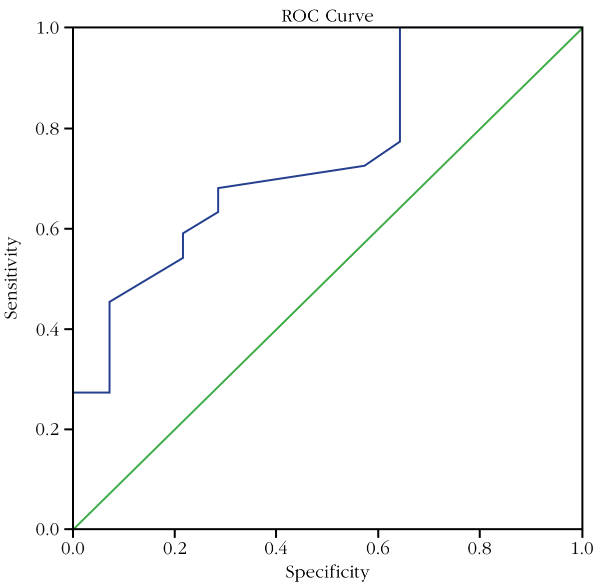


Figure 1. Ratio of injuries by nerve (%).

who had bilateral lumbosacral plexopathy damage more clearly on the left, reinnervation potential was observed in the muscles innervated by the nerves originating from the sacral plexus more clearly on the right. The second patient, who underwent control EMG on the 50th day after the earthquake, had a severe partial lesion in the radial nerve in the right forearm and showed an approximately 50% increase in the compound motor action potential (CMAP) amplitudes of the radial nerve. In the third patient, whose EMG was performed two months after the quake and who had a subacute severe partial lesion of the ulnar nerve at the elbow level on the left where axonal degeneration was more pronounced, an increase of approximately 30% in the CMAP amplitudes of the ulnar nerve and a 20% increase in the sensory nerve action potential amplitudes were observed. In the fourth patient, whose control EMG was performed two months after the earthquake and who had a severe axonal lesion of the lower, middle, and upper trunk of the brachial plexus on the left, reinnervation potential was observed, particularly in the muscles innervated by the nerves originating from the middle and upper trunk. In the fifth and final patient, who underwent control EMG three months after the earthquake and had a subacute severe partial lesion, the sciatic nerve's axonal degeneration was more evident on the left, and an approximately 50% increase in the CMAP amplitudes of the peroneal and tibial nerves was observed.

(a)



(b)

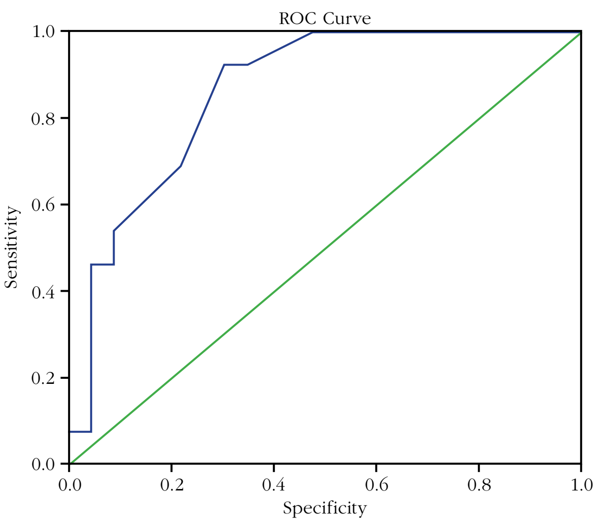


Figure 2. Receiver operating characteristic curve analysis **(a)** for crush syndrome (AUC: 0.747; p<0.014), sensitivity: 77.3%, specificity: 64.3%. **(b)** For compartment syndrome (AUC: 0.828; p<0.008), sensitivity: 71.4%, specificity: 51.3%.

ROC: Receiver operating characteristic; AUC: Area under the curve.

The mean time that the patients remained under rubble was 14.94±18.62 h (range, 1 to 76 h), and 61.1% of the patients developed crush syndrome. According to receiver operating characteristic (ROC) analysis, the risk of developing crush syndrome increased in patients who spent more than 6.5 h (area under the curve [AUC]: 0.747) under rubble. Among patients who developed the syndrome, a significant positive correlation also arose between time spent under rubble and the number of nerves affected (r=0.500, p=0.018). Meanwhile, 19.4% of patients developed compartment syndrome, and according to ROC analysis, the risk of developing the syndrome increased among patients who remained under rubble for more than 8.5 h (AUC: 0, 0.828), as shown in Figure 2.

DISCUSSION

Peripheral nerve injuries commonly occur in daily life due to trauma, traction, contusion, or penetrating trauma.[13] Along with the population's demographic characteristics and developmental level, the type and number of natural disasters (e.g., earthquakes) that it experiences affect the distribution, cause, and severity of those and other injuries.[10]

The effects of natural disasters are often unequally distributed among different sex and age groups. Previous research has shown that women are generally more commonly injured than men in disasters. For example, it was found that more women were injured in the 1995 Hanshin earthquake, the 2002 Afyon earthquake in Türkiye, and the 2001 Gujarat earthquake in India.[15-17] In a study evaluating the type of earthquake-related injuries and demographic characteristics following the earthquake in Italy in 2009, the female/male ratio was 63% versus 37%.[18] Considering that earthquake-related injuries are more common in women, the findings of this study, where we evaluated peripheral nerve injuries, were in line with the literature since women constituted 69.4% of our patients.

Hypotheses about why women are injured more often include that physiological characteristics put women at a disadvantage[19] and that their mobility may be restricted in the early stages of the disaster.[20] Other studies have shown that under certain conditions, social norms and role behaviors are important factors that increase women's vulnerability. For example, women are given the role of caring for and protecting children in the family, which may limit their ability to save themselves.[4,20]

In an analysis of studies on earthquake-related injuries published in the last 50 years, the parts of the body most frequently exposed to trauma were found to be the extremities.[21] Other studies have shown that lower extremity injuries are more common than upper extremity injuries after earthquakes.[11,22,23] In another study evaluating patients with musculoskeletal system injuries due to the February 6 earthquake in Türkiye, lower extremity injuries constituted 59.07% of all musculoskeletal injuries.[24] In our study, we evaluated peripheral nerve injuries after the February 6 earthquake and found that at least one lower extremity was affected in 61.3% of patients (four patients bilaterally and 15 patients unilaterally), which aligns with other results in the literature.

Electrophysiological methods applied early on following nerve injury allow determining the degree and distribution of nerve damage, determining the prognosis in subsequent serial examinations, observing the first signs of recovery preclinically, and determining the recovery rate.[25] In our study, the mean time for patients to apply to the EMG unit was 39.33±18.55 days.

According to the electrophysiological characteristics of the patients with peripheral nerve injuries in our study, the most common injury was in the sciatic nerve (30.6%). A single-center study in Mexico and a cross-sectional study of earthquake victims revealed that the sciatic nerve was the most frequently injured major nerve in the lower extremities.[10,26]

Guner et al.[27] also reported that the most common peripheral nerve injury in the 2011 Van earthquake was the sciatic nerve. Another study evaluating body positions and injured nerves in earthquake victims showed that sciatic nerve injuries occurred most frequently in patients who were trapped in a squatting position.[28] Since the sciatic nerve is on the hip extensor side, the sciatic nerve tightens when the hip joint bends, and if the nerve's tense state persists for a long time, injury may result.[28] Although we did not evaluate the patients' positions under the rubble in our study, that theory appears reasonable considering our patients, who remained under rubble for 14.94±18.62 h. Among other peripheral nerves damaged in patients in our study, the second most frequently affected nerve was the peroneal nerve (n=9, 25%), followed by the radial nerve (n=8, 22.2%). Similarly, in a study conducted after the 2003 earthquake in Bam, Iran, the most common nerve injury was in the sciatic nerve, and the second most common was radial nerve damage.[29] The high rates of radial nerve damage may be because the patients were not removed from the rubble in appropriate ways or positions.

In nerve injury, depending on the degree and duration of trauma, demyelination or axonal degeneration occurs in traumatized nerve segments, and motor and sensory functions are impaired in the distal part of the nerve. In a study evaluating spinal cord traumas, it was reported that the most significant damage occurred in the caudal segments of the lesion due to the direct effect of the trauma.[30] The duration and severity of the trauma suffered by the injured peripheral nerve determine the severity of functional loss and prognosis.[25]

In our study, all patients had partial axonal degeneration according to EMGs. Since our hospital was relatively undamaged in the earthquake, it served as a center where patients were referred from surrounding provinces. In turn, since most patients in our sample were referred from surrounding provinces, control EMG could be performed in five patients. In those control EMGs, performed on the 45th day at the earliest and the 90th day at the latest following the earthquake, regeneration potential and motor unit potential increased and dilution decreased in all patients. In Uzun et al.'s[11] EMG-based study on 75 victims of the 1999 earthquake in the Marmara region of Türkiye, regeneration was detected in all patients with brachial plexus damage at an mean follow-up of 3.5 months and in 62.5% of patients with peripheral nerve damage at an mean follow-up of 7.7 months. In a two-year follow-up of patients with peripheral nerve injuries treated conservatively after the Hanshin–Awaji earthquake in Japan, the prognosis of peripheral nerve paresis was positive in most patients.[12]

Crush syndrome was first defined by Bywaters and Beall[31] as hemodynamic and metabolic disorders and acute renal failure following muscle injury due to prolonged compression of a limb. The prolonged compression of skeletal muscle and the disruption of blood flow at the microvascular level are the chief mechanisms in the formation of crush syndrome. Although compression leading to the syndrome usually lasts at least 4 to 6 h, some cases have been reported following compression lasting less than 1 h.[32,33]

In our study, crush syndrome was detected in 61.1% of the earthquake victims, whose time spent under rubble varied from 1 to 76 h (mean time: 14.94±18.62 h). Moreover, the risk of developing crush syndrome increased among patients who stayed under rubble for more than 6.5 h, and a significant positive correlation emerged between time spent under rubble and the number of affected nerves in patients who developed the syndrome (r=0.500, p=0.018). In a study evaluating peripheral nerve damage in the 1999 earthquake in Marmara, crush syndrome was observed less frequently in pediatric patients than in adults, which the authors attributed to lower levels of muscle mass in children than in adults.[11] In another study on compressive peripheral nerve injuries in earthquake victims after the February 6 earthquake in Kahramanmaraş, the median time for victims to be removed from the rubble was 24 h (range, 1 to 180 h), and crush syndrome was detected in 58.2% of patients.[34] In yet another study analyzing the first 10 days of data after the same earthquake, 7.7% of 957 earthquake victims were found to have crush syndrome and 2.1% to have compartment syndrome.[35] Our rates may be low since our study was conducted early after the earthquake and did not include the analysis of the long-term results of patient follow-up.

In compartment syndrome, tissue perfusion stops due to increased intracompartmental pressure, and ischemia, damage, and necrosis develop in the muscle.[36] Intracompartmental pressure can put pressure on the nerves, and blood circulation through the nerves may be impaired due to compartment syndrome.[12] Peripheral nerve tissue is extremely sensitive to changes in oxygen tension, and peripheral nerve function may be lost within 30 to 90 min after the onset of ischemia.[37] A positive correlation has also been observed between the time spent under rubble and the degree of nerve damage.[38]

In our study, 19.4% of patients developed compartment syndrome, and the risk of developing the syndrome increased among patients who remained under rubble for more than 8.5 h. In Tahmasebi et al.'s[29] study on the victims of the 2003 earthquake in Bam, compartment syndrome was detected in 8.6% of patients, and a significant relationship was observed between time spent under rubble and the frequency of the syndrome. The authors thus emphasized the importance of early rescue efforts for improved outcomes.

Uzun et al.[11] investigated peripheral nerve damage after the Marmara earthquake and found that 41.7% of patients developed compartment syndrome and that the rate of the syndrome was higher among children than among adults. In another study including 957 victims of the February 6 earthquake, 2.1% had compartment syndrome.[35] Those authors emphasized that the rapid rescue of patients by advanced search and rescue teams and transportation to the nearest hospital are critical for the early treatment of compartment syndrome and crush injuries.

This study has several limitations that should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the findings to the broader population of earthquake survivors. Additionally, due to the chaotic and challenging circumstances following the disaster, it was not possible to follow up with all patients.

In conclusion, earthquakes are devastating disasters that cannot be prevented, just as their exact time, their location, and the severity of damage and injuries cannot be predicted. Peripheral nerve injury is one of the most common injuries experienced by earthquake victims, and lesions due to such injuries can cause temporary or lifelong disabilities. In our study, time spent under rubble significantly related to the severity of nerve injury and the development of compartment syndrome and crush syndrome. Thus, the possibility of peripheral nerve injury, which ranks among the prominent causes of morbidity, should be considered in the follow-up of patients who have survived earthquakes. In turn, the analysis of such injuries can provide valuable information for interventions, including rehabilitation, psychological treatment, economic cost assessment, and planning for future earthquakes.

Ethics Committee Approval: The study protocol was approved by the Harran University Clinical Research Ethics Committee (date: 21.08.2023, no: HRU/23.15.13). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept design, data collection and/or processing, literature review: T.G.D.; Control/supervision: K.B.E.; Analysis and/or interpretation, critical review, writing the article: T.G.D., K.B.E.

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