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Analysis of Neurosurgical Injuries and The Lessons Learned After the Catastrophic Double Earthquakes in Turkey

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ABSTRACT

AIM: Earthquakes are devastating natural disasters that cause mass casualties. Recently, a catastrophic double earthquake-affected ten cities with a population of 15 million in southern and central Turkey. We aimed to identify the patterns and types of neurosurgical injuries sustained by victims of the earthquakes.

MATERIAL and METHODS: In this descriptive observational study, we retrospectively analyzed the medical records of a university hospital located in one of the ten cities affected by the earthquake.

RESULTS: A total of 1,612 patients with earthquake-related injuries were admitted during the study period, of which 139 (8.6%) had neurosurgical injuries. The mean age of the patients was 42.4 ± 21.1 years (median, 42 years), and 53.2% of them were female. Of the 139 patients with neurosurgical injuries, 41 (29.5%) had craniocerebral injuries, 95 (68.3%) had spinal injuries, and three (2.2%) had both craniocerebral and spinal injuries. A total of 31 surgeries were performed (22.3%) (five [3.6%] for craniocerebral injuries and 26 [18.7 %] for spinal injuries). Ninety-eight patients (70.5%) had concomitant systemic traumas. The overall mortality rate was 5.75%, with crush syndrome (n=4, 50%), being the leading cause of death, followed by neurosurgical pathologies (n=3, 37.5%) and pneumonia with septic shock (n=1, 12.5%).

CONCLUSION: Neurosurgical injury is an important cause of post-earthquake mortality and morbidity. To ensure efficient medical rescue and judicious resource allocation, it is essential to recognize the characteristics of earthquake-related neurosurgical injuries. This study provides valuable information regarding the incidence, characteristics, and outcomes of neurosurgical injuries in earthquake-affected patients. Our findings highlight the need for prompt diagnosis and management of such injuries, particularly in those with concomitant systemic trauma.

KEYWORDS: Earthquake, Neurosurgical injuries, Trauma, Spine injury

INTRODUCTION

Earthquakes are among the most destructive natural disasters. Over the last 50 years, several populations have become increasingly susceptible to mortality and injuries from big earthquakes, coinciding with the growing global population and expanding urbanization (18,26). More than one million people have lost their lives due to earthquakes in the last 20 years (6).

A 7.8 M_w (moment magnitude scale) catastrophic earthquake struck southern and central Türkiye and northern and western Syria on February 6, 2023. This massive earthquake was centered at Kahramanmaraş and affected 10 cities with a total population of 15 million. A second 7.7 M_w earthquake occurred 9 h later, with its center 95 km to the northeast of Kahramanmaraş Province, making the disaster even more devastating. The primary shock was the greatest earthquake that had hit Turkey since the 1939 Erzincan earthquake, which was the

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second strongest earthquake in the nation's history after the 1,668 North Anatolia earthquake in terms of magnitude. More than 10 thousand aftershocks followed this earthquake. There was widespread damage of approximately 350,000 km^2, which is approximately the size of Germany. As of March 30, 2023, more than 50,000 deaths and 107,204 injuries had been confirmed.

Neurosurgical trauma is one of the most common injuries following musculoskeletal and abdominothoracic injuries. However, its clinical impact is much more catastrophic owing to the high rate of hospitalization and associated morbidity and mortality. Neurosurgical injuries can be classified as head and spinal traumas. Head injury, which accounts for 1.8–25.7% of injuries among earthquake victims, is one of the most common causes of mortality (11), with an overall rate of approximately 30% (3,14,17,23). However, spinal injuries, which comprise 13–15.2% of earthquake-related injuries, are associated with short- and long-term morbidity (4). Although several authors have reported the frequency of neurosurgical trauma, the factors that affect the results, such as the magnitude of the earthquake and geographic, climatic, and socioeconomic conditions, remain unclear (1,7,13). In this descriptive study, we aimed to describe the clinical picture of patients with neurosurgical injuries admitted to a tertiary hospital in the disaster region, identify the patterns and types of injuries, and investigate the factors affecting the morbidity and mortality of hospitalized victims.

MATERIAL and METHODS

This was an observational descriptive study based on the retrospective analysis of data collected from our hospital in the aftermath of the earthquake. Balcali Hospital is a large tertiary care hospital located in Adana, a city in the southern region of Turkey, which was one of the 10 cities affected by the disaster. The hospital is part of the Faculty of Medicine at Cukurova University, one of the leading medical schools in Turkey. The hospital has 1,050 beds, including 144 intensive care unit beds, and 1,063 medical doctors, 719 of whom are residents. We reviewed the medical records of patients with earthquake-related neurosurgical injuries who presented to the hospital during the 10 days following the disaster. Patients with injuries unrelated to the earthquakes were excluded from the study. The following data were collected: demographic data (age and sex), patterns and types of cranial and spinal injuries, location of injury, concurrent injuries, and treatment procedures. All the patients were clinically examined upon admission. Radiography, computed tomography scan, and magnetic resonance imaging were used to confirm neurosurgical pathologies. All patient data were anonymized and kept confidential to ensure privacy. The requirement for informed consent was waived owing to the retrospective nature of the study. The study was approved by the Institutional Research Ethics Committee (Date: 10 March 2023; No: 131).

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the study participants. The categorical variables are presented as frequencies and percentages, and the continuous variables are presented as means and standard deviations. The data have been presented in tables and graphs to aid the interpretation and visualization of the results. All analyses were performed using SPSS (version 23.0).

RESULTS

The earthquake affected a broad geographical area (Figure 1) (10). Between February 6 and February 16, 2023, a total of 1,612 patients with earthquake-related injuries were admitted to our hospital. Among the 1,612 patients, 139 (8.6%) had neurosurgical injuries. The mean age of the patients was 42.4 ± 21.1 years (median: 42 years, min–max: 1–88 years), and 53.2% (n=74) of them were female. The daily admission rates are shown in Figure 2. Of the 139 patients with neurosurgical injuries, 98 (70.5%) had a concomitant systemic trauma. The profile of all the injuries is shown in Figure 3. Additionally, among the 139 patients with neurosurgical traumas, 41 (29.5 %) had craniocerebral injuries, 95 (68.3 %) had spinal injuries, and three (2.2%) had both craniocerebral and spinal injuries. A total of 31 patients (22.3%) underwent surgery (five [3.6%] with craniocerebral injuries and 26 [18.7%] with spinal injuries). The characteristics and types of surgical intervention for craniocerebral and spinal traumas are presented in Tables I and II, respectively. The overall mortality rate in the study population was 5.75%. The reasons for mortality were neurosurgical pathologies (n=3, 37.5%), crush syndrome (n=4, 50%), and pneumonia with septic shock (n=1, 12.5%). Among the nonsurvivors, one patient was admitted on the second day, four on the third day, two on the fifth day, and one on the sixth day.

DISCUSSION

Earthquakes are the most devastating natural disasters, that have claimed more than one million lives over the last few decades (11). Neurosurgical injuries are a significant concern following earthquakes. These injuries can be caused by several factors, including falling debris, collapsing structures, and other forms of trauma. The time taken to rescue victims of earthquakes is critical; the longer it takes to reach and treat those with neurosurgical injuries, the greater the risk of permanent damage or even death. Herein, we have reported the injury characteristics and surgical interventions performed due to two massive earthquakes that recently occurred in Turkey. The frequency of craniocerebral injuries was 31.6% in patients with neurosurgical trauma, of which 54.5% were cranial fractures. Spinal injuries and other concomitant injuries individually accounted for 70.5% of all injuries.

During an earthquake, the first priority is to search for survivors and rescue those trapped under debris or rubble. This is a difficult and time-consuming process, and it can take hours or even days to locate and extract all the victims. During this time, those with neurosurgical injuries may be at an increased risk for mortality, because the lack of oxygen and access to medical treatment can exacerbate their condition. A postmortem examination of 51 victims of the 2011 Van earthquake

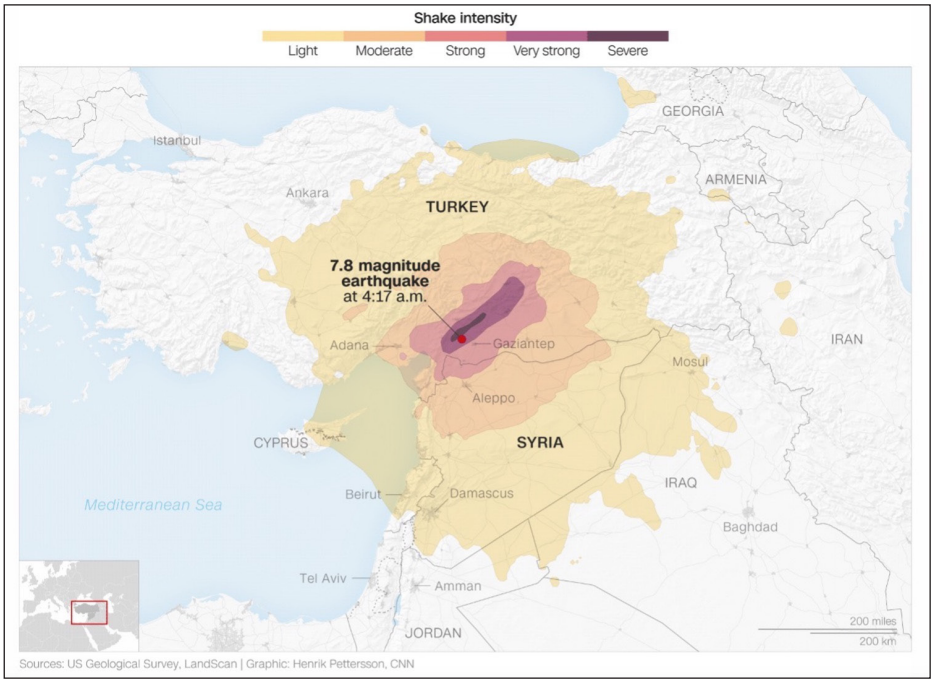

Figure 1: A map showing the affected areas according to the intensity of the earthquake. (Consent of the graph designer, Henrik Pettersson from CNN, was obtained for publishing the image).

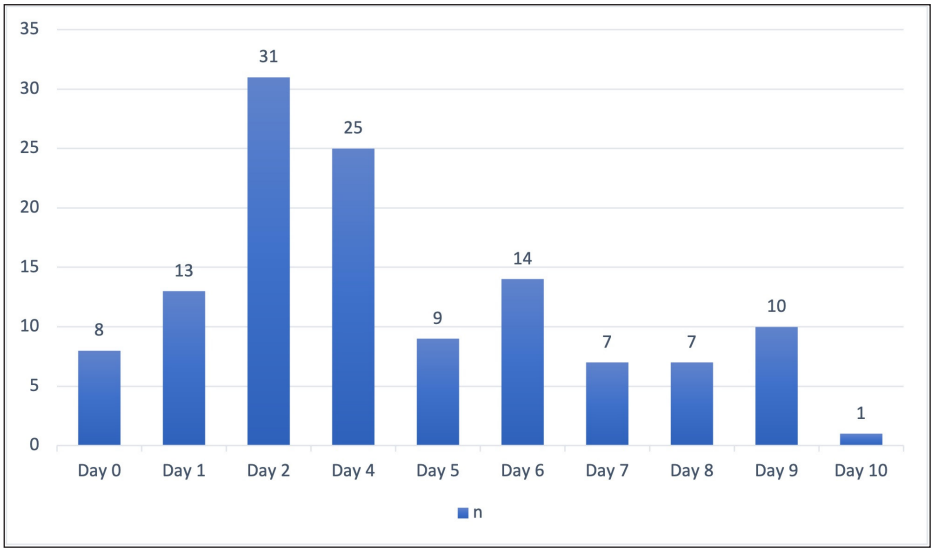

Figure 2: Daily patient admission numbers.

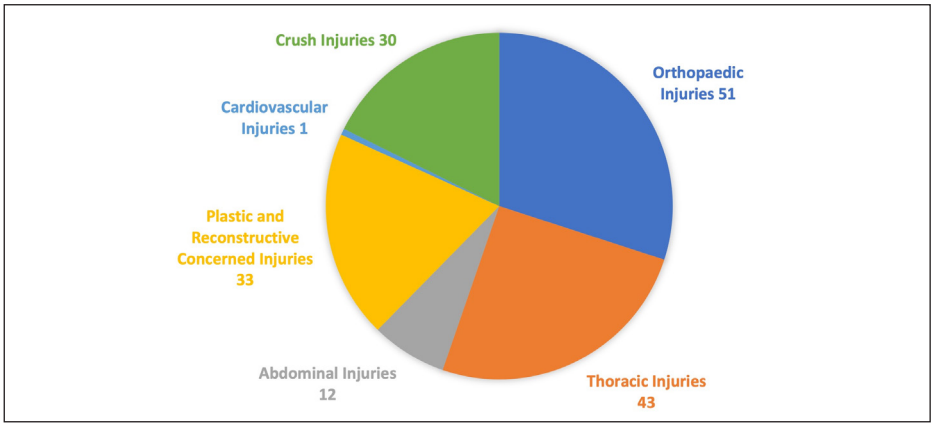

Figure 3: Number of patients with concomitant injuries.

Table I: Characteristics of the Craniocerebral Injury Patients

Variable	Frequency n=44	Percentage (100%)
Glasgow Coma Scale on Admission		
3-8	11	25.0
9-13	2	4.5
14-15	31	70.5
Cranial fracture	24	54.5
Linear	10	22.7
Depression	14	31.8
Cerebral contusion	14	31.8
Intraparenchymal haemorrhage	9	20.5
Epidural hematoma	7	15.9
Subdural hematoma	16	36.3
Cranial surgery	5	
Decompressive craniectomy	1	
Decompressive craniectomy + SDH evacuation	1	
Decompressive craniectomy + ICH evacuation	1	3.6
External ventricular drainage	1	
Subdural haemorrhage evacuation	1	

SDH: *Subdural Hematoma,* ***ICH:*** *Intracerebral Haemorrhage.*

Table II: Characteristics of the Spinal Injures

Variable	Frequency n=98	Percentage (100%)
Spinal fracture	98	70.5
Cervical	19	19.4
Thoracal	17	17.3
Lumbar	40	40.8
Multiple	22	22.5
Fractures in TL Junction (T10-L2)	53	54.0
Stable fractures	83	89.2
Unstable fractures	15	10.8
Spinal cord injury	8	8.2
ASIA Scores		
A	4	4.1
B	1	1.0
C	0	0
D	7	7.1
E	86	87.8
Fracture type		
Compression	34	34.7
Burst	4	4.1
Dislocation	1	1.0
Lateral and posterior elements	44	44.9
Multiple	16	16.3
Spinal surgery	26	26.5
Kyphoplasty	9	9.2
Decompression + Posterior stabilization	12	12.2
Posterior decompression	1	1.0
Anterior cervical discectomy + stabilization	2	2.1
Spinal epidural hematoma evacuation	1	1.0
Cervical + Lumbal decompression + stabilization	1	1.0

ASIA: *American Spinal Injury Association,* ***TL:*** *Thoracolumbar.*

revealed that visceral and cranial injuries accounted for 58.8% of all deaths, and 27.5% deaths occurred due to mechanical asphyxia (9). Traumatic brain injury (TBI) is the most common cause of on-site mortality in earthquake victims (8). The Glasgow Coma Scale (GCS) is a widely used prognostic scale to evaluate an individual's neurological status. TBI is classified as mild (13–15), moderate (9–12) and severe (3–8) according to the GCS (12). Aycan et al. reported that 91.7% of patients with earthquake-related TBI had mild TBI. Moreover, none of the patients in their cohort had severe TBI (1). Similarly, Bhatti et al. reported that 89.3% of the 300 patients with earthquake-related head trauma in their cohort had mild and moderate craniocerebral injuries (3). Our results are in accordance with those of previous studies; the vast majority of our patients had mild TBI and underwent only a limited number of operations.

According to a recent systematic review, among the survivors admitted to a hospital, 59.2% have lacerations or cerebral contusions, 32.3% have skull fractures, and 22.1% have intracerebral hematomas. Additionally, epidural hematomas (9.5%), followed by intracerebral (7.0%) and subdural (6.8%) hematomas, are reportedly the most common types of intracranial hemorrhages (11). In our study, 54.5%, 31.8%, and 72% of the admitted patients had skull fractures, contusions, and hematomas, respectively. Furthermore, more patients had subdural hematomas than epidural hematomas (11.5%) in our study. This is because patients with epidural hematomas may have died before arriving at our hospital for medical care. This may also be the underlying reason for the higher rate of non-significant injuries requiring surgical intervention. Only 11.4% of the patients with craniocerebral injuries required surgical intervention. This finding is similar to that of a previous systematic review in which the rate of a major surgery, such as craniotomy, hematoma evacuation, and cranial repair under

general anesthesia, being performed was 15.5% (11). Despite the high rate of intracranial hemorrhages in our study, the lower surgical rate can be explained by the following reasons: (i) on-site death of severe cases and the devoted work of the neurosurgical teams at surviving hospitals that performed emergency surgeries; and (ii) the rapid organization and immediate mobilization of neurosurgical teams from all over the country to the epicenter of the disaster by the Turkish Neurosurgical Society to provided support. Thus, more emergency surgeries were performed in the region, and stable patients who required follow-up were transferred to hospitals such as ours.

Time taken to rescue an individual is a key determinant of post-earthquake mortality. The importance of "golden hours" has been repeatedly emphasized in previous studies. The overall mortality rate in our study was 5.7%. Additionally, most of the patients (87.5%) who did not survive were admitted to our hospital 72 hours after the earthquake. This finding supports the key role of admission time, which is crucial in determining the patient's prognosis. The speed of rescue efforts is reportedly directly associated with survival rates following earthquakes. If earthquake victims are rescued and hospitalized earlier, the survival rates, including mortality rates, are better (19). Another determining factor of mortality may be multiorgan trauma. Earthquake-related neurosurgical injuries are frequently accompanied by orthopedic, thoracic, and abdominal injuries, and some patients may develop crush syndrome. Bulut *et al.* determined that crush syndrome increases the mortality risk by 21.7 times (3). The frequency of multiorgan trauma in our study was higher than that in previous studies (5,15,27). This may be explained by the time at which the first earthquake occurred; the victims had been lying in supine or lateral positions. Orthopedic injuries, including pelvic and thoracic injuries, are more common in these positions (22).

In addition to mortality, long-term morbidity is a catastrophic effect of earthquakes. Spinal injuries are associated with significant long-term morbidity because they require long-term support and rehabilitation. Earthquake-related spinal injuries can have serious and long-term effects on the victims. During an earthquake, spinal injuries can occur when the spinal column is subjected to extreme forces and can be classified as spinal cord injuries and spinal column injuries. These injuries can vary in severity and location, and their effects on the victim depend on the extent of the injury. In our study of 139 patients, 98 (70.5%) had spinal injuries, and only eight had spinal cord injuries. Similar to previous studies, our cohort mostly consisted of patients with lumbar spinal injuries (40.8%), followed by multiple spinal (22.5%) and thoracic spinal fractures (17.3%) (5,24). Approximately 54% of these spinal fractures were located at the thoracolumbar junction (T10–L2). This may be due to the fact that the thoracolumbar region, which is the transition zone from a partially immobile to a mobile spine segment, is more vulnerable to traumatic forces than other spinal regions. Alternatively, it may be explained by the fact that the larger vertebrae are more exposed to trauma than smaller vertebrae, as determined by Dong et al. The T12–L3 region had the highest incidence of spinal injuries in their study (4). Approximately 4.9–9.0% of patients with spinal column fractures reportedly have spinal cord injuries (16,20,21,25). Similarly, we found that 8.2% of the 98 patients with spinal fractures had spinal cord injuries. The majority of spinal fractures in our study were stable fractures; only 10.8% of the fractures were unstable. The low rate of unstable fractures explains the low rate of spinal operations performed. The nine kyphoplasties performed in the study were for simple compression fractures.

This study had several limitations. It was a retrospective analysis of medical records, which may not appropriately reflect all the injuries sustained during the earthquake. Moreover, we were unable to control for confounding variables or measure long-term outcomes. Additionally, the study period was only the ten days following the earthquake; thus, long-term injuries and health effects could not be evaluated. Finally, the study was conducted at a single center and may not be representative of all earthquake-related neurosurgical injuries and of all the other affected areas.

CONCLUSION

In conclusion, for efficient medical rescue, judicious resource allocation, quick triage, and timely treatment, it is essential to recognize the characteristics of earthquake-related neurosurgical injuries. Knowledge of the neurosurgical injury characteristics benefits the ability to summarize the experiences and lessons learned, cope with destructive disasters, and organize medical rescue systems more effectively. This includes the organization of adequate staff, equipment, and resources to manage the surge in patients in the aftermath of an earthquake. Our study findings have important implications regarding disaster planning and preparedness. It is important for health care systems to have a comprehensive disaster plan that includes provisions for neurosurgical services. Furthermore, early intervention and adequate disaster planning are critical to improve the outcomes of patients with earthquake-related neurosurgical injuries. Further research with larger and more diverse samples is required to externally validate these findings and better understand the long-term outcomes and healthcare needs of earthquake survivors with neurosurgical injuries.

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AUTHORSHIP CONTRIBUTION

Study conception and design: NEC
Data collection: AA, AA, GA
Analysis and interpretation of results: KMO, KO
Draft manuscript preparation: NEC, KMO
Critical revision of the article: TE
All authors (NEC, AA, AA, GA, KMO, KO, TE) reviewed the results and approved the final version of the manuscript.

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