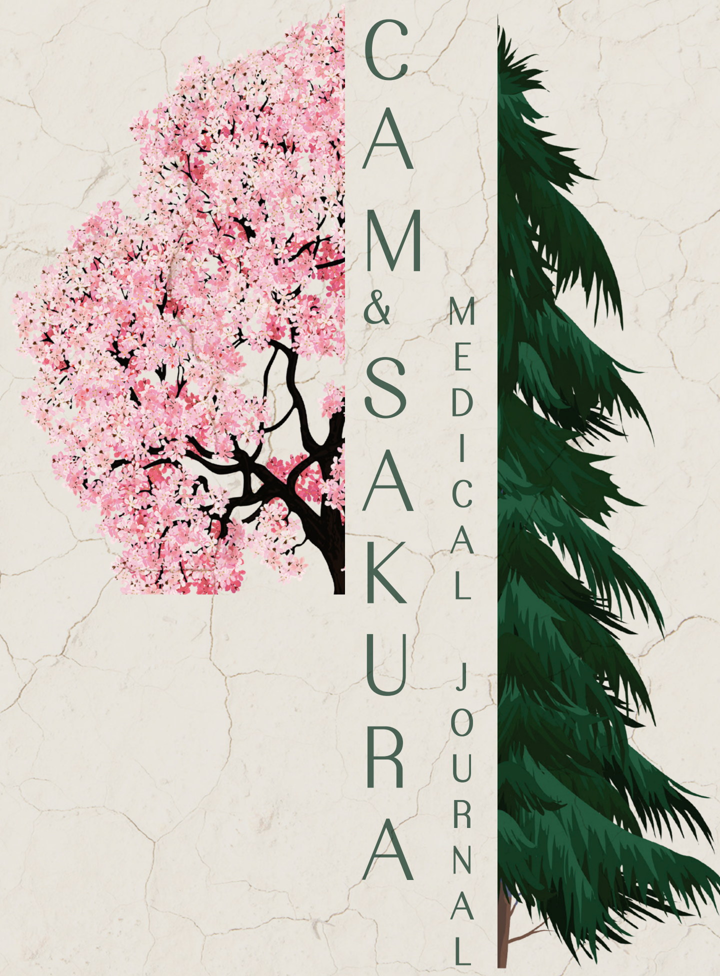
E-ISSN: 2791-8823

REPUBLIC OF TURKEY MINISTRY OF HEALTH
BAŞAKŞEHİR ÇAM & SAKURA CITY HOSPITAL

CSMJ

THE JOURNAL OF BAŞAKŞEHİR ÇAM AND SAKURA CITY HOSPITAL

Approach to the Deadliest Earthquakes: From Multidisciplinary Perspective



December
2023 Volume: 3 Issue: Suppl-1

www.csmedj.org
galenos Publishing House

CSMJ

Volume: 3 · Issue: Suppl 1 · December 2023

Editorial Board

ÇAM & SAKURA MEDICAL JOURNAL

CSMJ

Volume: 3 • Issue: Suppl 1 • December 2023

galenos yayınevi

Publisher Contact
Address: Molla Gürani Mah. Kaçamak Sk. No: 21/1
34093 İstanbul, Turkey
Phone: +90 (530) 177 30 97
E-mail: info@galenos.com.tr/yayin@galenos.com.tr
Web: www.galenos.com.tr
Publisher Certificate Number: 14521

Printing at: Son Sürat Daktilo Dijital Baskı Merkezi Sanayi ve Ticaret Ltd. Şti.
Gayrettepe Mahallesi, Yıldızposta Caddesi, Evren Sitesi A Blok No: 32
D: 1 - D: 3 34349 Beşiktaş, İstanbul, Turkey
Phone: +90 (212) 288 45 75 **E-mail:** info@sonsuratdaktilo.com
Printing Date: December 2023
E-ISSN: 2791-8823
International scientific journal published quarterly.

Editorial Board

CSMJ

Volume: 3 · Issue: Suppl 1 · December 2023

CSMJ

Volume: 3 · Issue: Suppl 1 · December 2023

Editorial Board

Editorial Board

Please refer to the journal's webpage (**https://csmedj.org/**) for "Ethical Policy", "Aims and Scope" and "Instructions to Authors".

The editorial and publication process of Cam and Sakura Medical Journal are shaped in accordance with the guidelines of the ICMJE, WAME, CSE, COPE, EASE, and NISO. The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing.

Cam and Sakura Medical Journal is indexed in **DOAJ, J-Gate, Türk Medline, EBSCO** and **Gale**.

The journal is published electronically.

Owner: Başakşehir Cam and Sakura City Hospital

Responsible Manager: Merih Çetinkaya

CSMJ

Volume: 3 · Issue: Suppl 1 · December 2023

Contents

CSMJ

Volume: 3 • Issue: Suppl 1 • December 2023

Editorial

Dear Colleagues,

It was a real tragedy for Turkey to awake up the early morning on 6 February 2023, with a magnitude 7.8 earthquake that occurred in southern Turkey. It was followed approximately nine hours later by a magnitude of 7.5 earthquake located in the same area including 11 cities as Adıyaman, Hatay, Kahramanmaraş, Kilis, Osmaniye, Gaziantep, Malatya, Şanlıurfa, Diyarbakır, Elazığ, and Adana. In these cities almost 14 million people were living. These two eathquakes produced more than 200 aftershocks, some were really severe. According to the latest statements, more than 50,000 people died and more than 100,000 people were injured after these two major earthquakes. Also a total of 9.1 million people were estimated to be are affected by the earthquake disaster, and 3 million people have been displaced.

These earthquakes also destroyed more than 200,000 buildings, including some hospitals. Several medical professionals including phycians, nurses, technicians, secretaries, students and also volunteers worked hardly and in coordination to help injuried people. In addition, several medications and emergency supplies, urgent trauma care, psychosocial assistance, infection control measures and post-trauma rehabilitation services were tried to be administered in all these cities. Therefore, this earthquake disaster forced us to publish a special issue for all health care systems to be more prepared for the possible future disasters in Turkey and other countries. Hence, we are just publishing the Cam Sakura Medical Journal Special Issue entitled as "Approach to the deadliest earthquakes: from multidisciplinary perspective."

You can read different articles about the management of injured people due to disasters in this special issue. Herein, you can read the article about the organization of healthcare systems in the disaster areas. You can also find the articles about the management of injured people in both emergency services and also orthopedics triages. In addition, you can read two articles about the magament of injured cases in both pediatric and adult intensive care units. As we used extensively hyperbaric oxygen therapy in most of these patients, you can find an article about this topic, Lastly, you can read the article about prevention of infectious diseases and protection of public health just after these kind of disasters. As these disasters may occur at any time in all around the world, it is more important to take cautions and to be ready for management. We think that these articles will make us to be more prepared and be more experienced for future disasters.

As the Editor in Chief, I want to thank to Prof. Nurettin Yiyit, Chief Coordinator Physcian of Başakşehir Çam and Sakura City Hospital for encouraging efforts for the preparation and publishment of this special issue. I also want to thank to Special Issue Editors Mehmet Bülent Balioğlu and Hüseyin Şehit Burhan for their valuable efforts during the preparation of this issue.

We all wish you a happy new year.

Merih Çetinkaya
Professor, MD, PhD
Editor in Chief

Mehmet Bülent Balioğlu
Associate Professor, MD
Special Issue Editor

Hüseyin Şehit Burhan
Associate Professor, MD
Special Issue Editor

DOI: 10.4274/csmedj.galenos.2023.2023-9-2
Cam and Sakura Med J 2023;3(Suppl 1):1-3

CSMJ

Organization of Health Services for Earthquake Victims in the Area

Şakir Ömür Hıncal

University of Health Sciences Turkey, Bağcılar Training and Research Hospital, Clinic of Emergency Medicine, İstanbul, Turkey

ABSTRACT

In this review article, I wanted to explain my experiences as the Chief Physician of the İstanbul Provincial Ambulance Service with current literature information, especially the difficulties encountered in the organization of emergency health services at the area for earthquake victims, how emergency health services were organized in the earthquake region, and how patient transfers were made.

Keywords: Earthquake, emergency medicine, health services

Introduction

On February 6, 2023, two earthquakes with magnitudes of Mw 7.8 (±0.1) and Mw 7.5 occurred with epicentres in the Pazarcık and Elbistan districts of Kahramanmaraş, respectively. The earthquakes were followed by more than 40 thousand aftershocks with magnitudes up to Mw 6.7. It caused damage over an area of approximately 350,000 km^2 and affected 14 million people, 16% of Turkey's population. It was recorded as the largest, longest, and most severe earthquake in the history of the Republic of Turkey. It is estimated that 50 thousand people lost their lives and 115 thousand people were injured. After this major disaster, the Turkish government announced that a level 4 alert was declared for the earthquake zone, which is the highest level of emergency that covers calls for help from international organizations and countries in emergencies such as natural disasters and epidemics. In addition, a state of emergency was declared for 3 months in 10 provinces affected by the earthquakes, while the World Health Organization declared a level 3 emergency for the earthquakes that shook Turkey. Following the earthquake, 21% of public hospitals and 17% of private hospitals were damaged. A total of 41 hospitals in the region were rendered unusable, 14 of which were moderately and 13 of which were severely damaged, and 14 of which were moderately and severely damaged. Hatay (56%), Kahramanmaraş (50%), and Gaziantep (50%) were the provinces with the most damaged public hospitals. Malatya (86%), Adıyaman (50%), and Hatay (40%) had the most damaged private hospitals (1).

In this review article, I wanted to explain my experiences as the Chief Physician of the İstanbul Provincial Ambulance Service with current literature information, especially the difficulties encountered in the organization of emergency health services in earthquake-affected areas, how emergency health services

Address for Correspondence: Şakir Ömür Hıncal MD, University of Health Sciences Turkey, Bağcılar Trainig and Research Hospital, Clinic of Emergency Medicine, İstanbul, Turkey
Phone: +90 212 440 42 10 **E-mail:** omur.hincal@gmail.com **ORCID ID:** orcid.org/0000-0002-2116-7710
Received: 20.09.2023 **Accepted:** 01.12.2023

CAM & SAKURA MEDICAL JOURNAL

were organized in the earthquake region, and how patient transfers were made.

The collapse of the Gaziantep-Adana highway and severe winter conditions caused difficulties for ambulance and rescue teams travelling to the region from other provinces. Hatay airport was rendered unusable, making it impossible for patients to be transferred from the region. In addition to affecting normal citizens and buildings, the earthquakes also affected health institutions and health workers living in the region. The death or inability of health workers in earthquake zones and damage to health facilities because of the earthquake can make normal supply chains inaccessible and disrupt the overall functioning of the health system. health personnel were not able to work in the first days, many health personnel lost their lives in the earthquake, and the surviving health personnel had to deal with the health or death problems of their families. This situation has created problems in terms of health needs arising after the earthquake and health services that can respond to these needs. The Ministry of Health initially assigned doctors to the region in the branches of emergency medicine, anesthesia and reanimation, and orthopedics. Later, doctors and auxiliary health personnel, including internal medicine, nephrology, gynaecology and obstetrics, urology, neurosurgery, ophthalmology, plastic and reconstructive surgery, cardiovascular surgery, paediatric surgery, and thoracic surgery, were assigned to the region to ensure the organisation and functioning of the interrupted health services. To make health services operational, it was necessary to send health aid consisting of health workers, medical supplies, and basic equipment to the affected provinces. It was also necessary to transport the wounded from the region.

National Medical Rescue Team [NMSR (*Ulusal Medikal Kurtarma Ekibi, UMKE*)], and 112 emergency medical teams dispatched to the earthquake zone by the General Directorate of Emergency Health Services of the Ministry of Health participated in search and rescue operations in collapsed buildings, installation and operation of emergency response units, and field surveys. In addition to 850 ambulances, 51 NMSR vehicles, and 7,839 NMSR, and 112 emergency healthcare personnel, 1,253 ambulances, 245 NMSR vehicles, and 6,596 NMSR and 112 emergency healthcare personnel were deployed nationwide. NMSR provided first interventions under the rubble during search and rescue operations, treatment of the wounded who applied to the emergency response units, and transport of the wounded who needed to be transferred to hospitals by 112 emergency medical teams. NMSR and 112 emergency medical teams organised visits to the villages affected by the earthquake in the regions where search and rescue operations were completed and provided outpatient clinic services and medical care within the scope of home health care. Basic necessities, which were difficult to provide due to the difficulty of transportation, were provided from the aid centers and delivered to the villages. To meet the health needs in the region, 77 field hospitals and medical intervention tents were established by the General Directorate of Emergency Health Services (2). To set up field hospitals and maintain health services in each province affected by the earthquake, a coordination chairman and two vice chairmen were identified from the administrators of other provinces, and health coordination in the provinces was ensured. Tents and prefabricated structures were set up to meet the accommodation and logistic needs of the health personnel assigned to the region. Medical aid from all over Turkey was transported to the region by road. More than 30 lorries containing medical supplies, sheltering materials, and consumables were sent by the İstanbul Emergency Health Services Directorate. 13,370 injured people were transported to hospitals in different cities by land ambulances, 1,715 injured people were transported by air, and 327 injured people were transported to hospitals in different cities by the TCG İskenderun ship of the Ministry of National Defence. The Air Operation Centre of the General Directorate of Emergency Health Services of the Ministry of Health coordinated the air transfer of sick and injured earthquake victims to hospitals in other cities. Air ambulances with 4, 2, and 1 stretcher, helicopter ambulances, and Turkish Armed Forces (TAF) cargo-type aircraft were used to transport the injured from Adıyaman, Gaziantep, Malatya, Kahramanmaraş, Mersin, Adana, Hatay, Şanlurfa, Diyarbakır, and Kayseri. Following the earthquakes centred in Kahramanmaraş, 1,715 patients were transferred to hospitals in different cities by aircraft and helicopters (3). On the first day of the earthquake, considering both the land traffic and the urgency of the patients, helicopters of the Ministry of Health and helicopters of the TAF transported patients from Hatay to nearby cities. The wounded who were transported by aircraft were treated in hospitals in Ankara, İstanbul, İzmir, Adana, Kayseri, and Antalya. In addition, patients were transported to Gaziantep, Diyarbakır, Malatya, Konya, and Eskişehir by ambulance planes. On the first day of the earthquake, patients brought to İstanbul by TAF cargo planes and Ministry of Health aircraft ambulances were transferred to hospitals under the coordination of the İstanbul European Provincial Ambulance Service Chief Physician. They were transferred to hospitals throughout İstanbul, especially Başakşehir Çam and Sakura City Hospital, and Bağcılar Training and Research Hospital by

112 emergency health ambulances. Patients whose treatment was completed in hospitals and who required inpatient transfer were also transported back by 112 emergency health ambulances.

Urgent action is needed to prevent future disasters from having a similarly devastating impact. Health managers should analyse the problems experienced in this disaster and obtain feedback from the personnel who have worked in the earthquake zone and listen to their suggestions. The problems experienced in the health system during the earthquake should be identified and improvements should be made. Turkey's healthcare system must ensure that because of these earthquakes, disaster preparedness and response planning must be prioritized. This response should entail a comprehensive and well-coordinated plan involving all relevant stakeholders, such as government agencies, healthcare providers, and local communities. Investments in infrastructure, equipment, and personnel, as well as ensuring an adequate supply of medical supplies and equipment, are all part of this plan. To ensure effective response and support for those in need, disaster preparedness and response planning must be prioritized.

Ethics

Peer-review: Externally peer-reviewed.

Financial Disclosure: The author declared that this study received no financial support.

REFERENCES

1. Birinci Ş. Technical efficiency of post-disaster health services interventions: the 2023 Kahramanmaraş Earthquake in Turkey. Int Journal of Health Manag and Tourism 2023;8:187-203.
2. Available from: https://acilafet.saglik.gov.tr/TR-94867/kahramanmaras-depremi-calismalarimiz.html
3. Available from: https://www.aa.com.tr/tr/asrin-felaketi/devletin-hava-araclari-yuzlerce-yarali-depremzedenin-imdadina-yetisti/2818932

REVIEW

DOI: 10.4274/csmedj.galenos.2023.2023-9-8

CSMJ

Cam and Sakura Med J 2023;3(Suppl 1):4-13

CAM & SAKURA MEDICAL JOURNAL

Approach to Earthquake Victims at Emergency Services: A Review and Analysis of Current Practices

Önder Yeşiloğlu[1], Serkan Doğan[2], Akkan Avci[3]

[1]25 Aralık State Hospital, Clinic of Emergency Medicine, Gaziantep, Turkey

[2]University of Health Sciences Turkey, Kanuni Sultan Süleyman Training and Research Hospital, Clinic of Emergency Medicine, İstanbul, Turkey

[3]University of Health Sciences Turkey, Adana City Training and Research Hospital, Clinic of Emergency Medicine, Adana, Turkey

ABSTRACT

Earthquakes are natural catastrophic phenomena that cause huge destruction to human society, causing loss of lives, mass injuries, and property damage. In the last decades, there have been a series of major earthquakes that had severe impacts on populations, notably those in Turkey, Iran-Iraq, Nepal, China, and Haiti. This review was undertaken with searches of indexed online databases such as PubMed, Google Scholar, Scopus, and Web of Science (core collection) for existing literature, guidelines, protocols, and best practices to diagnose and treat earthquake victims in emergency settings. Timely diagnosis and treatment of traumatic injuries and related conditions such as Crush syndrome and rhabdomyolysis after earthquakes are imperative to provide the best chances of survival to patients. Possible later complications such as neurovascular events and infections may contribute to reduced mortality and morbidity rates and should be addressed accordingly. Improved communication, collaboration between different healthcare departments, and coordination between healthcare facilities in the immediate disaster zone can help optimize resources and minimize delays in diagnosis, treatment, and transport of patients. Combined with well-established triage protocols and a dedicated team of physicians from multiple disciplines, emergency departments should prioritize the allocation of limited resources to ensure that patients with urgent and life-threatening injuries receive timely and appropriate care. Timely diagnosis and treatment of traumatic injuries and related conditions such as Crush syndrome and rhabdomyolysis after earthquakes are imperative to provide the best chances of survival to patients.

Keywords: Earthquakes, Turkey, emergency, Crush syndrome, rhabdomyolysis

Introduction

Earthquakes are natural catastrophic phenomena that cause huge destruction to human society, causing loss of lives, mass injuries, and property damage. In the last decades, there have been a series of major earthquakes that had severe impact on populations, notably those in Turkey [2023, MW 7.6 (moment magnitude scale), Kahramanmaraş], Iran-Iraq (2017, MW 7.6, Kermanshah), Nepal (2015, MW 7.8, Ghorka), China (2008, MW, 8.8 Sichuan), Turkey (2020, MW 6.7, Elazığ), and Haiti (2010, MW 7.0, Port Au Prince). In some of these, the loss of lives was documented to have been in

Address for Correspondence: Assoc. Prof. Akkan Avci, University of Health Sciences Turkey, Adana City Training and Research Hospital, Clinic of Emergency Medicine, Adana, Turkey

Phone: +90 533 423 03 69 **E-mail:** drakkanavci@gmail.com **ORCID ID:** orcid.org/0000-0002-4627-0909

Received: 30.09.2023 **Accepted:** 14.12.2023

thousands or even more. Emergency care for earthquake-related traumatic injuries has long been a key part of disaster medicine, as such catastrophes necessitate urgent treatment of require tens of thousands of traumatically injured victims within hours. Survivors face numerous risks in a critical time period that can best be depicted as "hours to days", they could be trapped in rubble, crushed under falling debris, suffering from severe limb injuries that can lead to amputations, head injury, or suffocation, while facing the possibility of secondary disasters like fire or flash flooding. Overwhelmed emergency systems, limited resources, and fragile infrastructure often impair emergency response in large scale events that cause mass casulties. Therefore, early recognition of life-threatening conditions among earthquake survivors and initiating treatment in a timely manner remains the main focus for disaster response. This review aims to discuss some important aspects of emergency care of earthquake survivors who were referred to emergency departments (EDs) in the days following an earthquake while providing examples from across various studies based on major earthquakes across the globe.

This review was undertaken with searches of indexed online databases such as PubMed, Google Scholar, Scopus, and Web of Science (core collection) for existing literature, guidelines, protocols, and best practices to diagnose and treat earthquake victims in emergency settings. Keywords "earthquake, emergency, triage, trauma, post-earthquake" were used. Search strategies included reviewing all titles and abstracts of potentially relevant articles and/or examining the full texts of selected references. Available literature on emergency preparedness and disaster planning before, during, and after major earthquakes, epidemiological studies on the incidence and distribution of injuries caused by earthquakes, and the role of primary, secondary, and tertiary care providers in earthquake-affected regions were also included.

1. Epidemiology and Demographics

In the wake of a major earthquake, demographic variables can have a considerable impact on the approach to patients in the ED. Age, gender, and socioeconomic status can influence the severity of injuries, response to treatment, and prognosis. For instance, older individuals may be more susceptible to fractures and other age-related injuries, whereas females are at a risk of reproductive and gynecological complications (1). In addition, lower income areas tend to have limited access to medical care, which may exacerbate pre-existing conditions and increase the mortality rate. Therefore, it is crucial for emergency personnel to be aware of these potential differences and adjust their treatment plans accordingly.

According to several studies, there has been a marked difference in the number of injuries between genders. In the aftermath of the Wenchuan earthquake in 2008, 50.4% (n=1148) of the 2,278 registered survivors were women (2). Similarly, following the Kathmandu earthquake in 2015, 53% (n=883) were females among the total of 1,668 patients included in study (3). In the case of the 2020 Samos earthquake, the percentage of men and women (i.e., 39.5% vs. 60.5%, respectively) was further skewed toward female gender (4). Again, females were shown to be more prone to injuries during earthquakes in Mexico City (2017), Kahramanmaraş, and Haiti (2010) (Doocy) according to various studies and databases (5,6,7). Gender appears to play a role in determining the incidence and distribution of injuries caused by earthquakes, and admissions to EDs.

Elderly people may find it difficult to leave their homes after an earthquake because they may not be able to react quickly. Older persons may also have additional medical conditions, which makes them prone to environmental exposure and puts them at a greater risk of hemodynamic instability following the disaster. However, statistical data suggest that while older individuals are potentially at greater risk of injuries, they are not one of the age groups with a higher overall frequency of emergency care presentations. Only 5.3% of the 80.2% of victims who were admitted as survivors to the emergency services in the wake of the 2023 Kahramanmaraş earthquake were elderly, and the elderly patient ratio was 7.6% among the deceased patients (6). Additionally, after the 2020 Erzincan-Elazığ earthquake in Turkey, which occurred at night, people between 18 and 59 years old were found to be the most injured. The mean age of patients admitted to the ED of a university hospital following the Elazığ-Turkey earthquake was 37.3 (8), and the age group between 18 and 59 was found to be the most severely injured during the 2010 Haiti earthquake (7).

Pediatric patients are also at a higher risk of injuries compared with adults, according to various studies. Following the earthquake in Haiti, 53% of patients were under the age of 20, and 25% were under the age of five; 25% of patients in India were under the age of 17 (9) while 25% of patients in the aftermath of 2001 earthquake in Gujarat, India were under the age of 17 (10). Children may have an increased risk of respiratory injuries because of their smaller airways and reduced chest wall compliance. Despite their smaller body weight and size, injury patterns in the pediatric population have shown a significant incidence of fracture-related injuries (30.6%) and wounds, as well as frequently reported crush injuries. The approach to pediatric victims may require teaming up with general pediatricians and child health specialists as well as pediatric trauma surgeons (11).

2. Triage, Organization, and Initial Assessment

Earthquakes often create mass casualties that can overwhelm the response capacity of health facilities and healthcare personnel. Effective management of resources is imperative to minimize delays and further losses. To achieve the best results, a post-disaster medical rescue effort must be well organized and coordinated (12). During the first hours and days immediately following a disaster, emergency rooms (ERs) face several challenges. They need to prioritize treatment for those who are most in need; perform rapid diagnosis and appropriate decision-making; decide what kinds of interventions could help patients; and make arrangements for transportation of the patients to appropriate care centers while considering whether there is adequate equipment, medications, and staff members to respond to and care for patients.

Research shows that there are issues with emergency services communication systems, a shortage of emergency vehicles, and a higher incidence of airport closures after earthquakes with magnitudes greater than six (13). Due to phone line congestion following the Niigata Chuetsuoki earthquake, emergency calls on the day of the earthquake could not be fully attended to until approximately 12:00 hours. Subsequently, between 12:00 hours and 17:00 hours, a sizable percentage of the vehicles had to be set aside for use in hospital transfers; it was not until 18:00 hours that most ambulances could again be dispatched to emergency scenes (14). Further, rescue and medical personnel may become victims themselves, and local healthcare facilities can be damaged by the earthquake. All medical facilities within a 75-km radius of the epicenter of the 7.3-Mw earthquake were destroyed following the 2017 Kermanshah earthquake in Iran (15). In Hatay, Turkey, several private hospitals as well as two tertiary hospitals and a district public hospital sustained significant damage as a result of the 2023 Kahramanmaraş earthquake (16). To mitigate these situations, some steps should be taken prior to a disaster, such as preparing disaster plans, conducting periodical trainings and simulations, and setting up contingency arrangements with other facilities for worst-case scenarios. According to Schultz et al. (17), the distance of a hospital from the epicentre within the immediate disaster zone cannot effectively estimate the danger of damage to that facility. As a result, direct patient transportation from the disaster area to a secondary hospital could be beneficial. This precaution may also help ease the burden of hospitals within the immediate vicinity of the earthquake, since the difference in hospital arrival time is associated with mortality, with the mean time of emergency service admission being later (>9 hours) in survivors compared with non-survivors, which can be attributed to better capacity to provide care to patients in the latter days of an emergency response (4). China and Japan, two Asian countries with a long history of major earthquakes, seem to have successfully implemented pre-hospital disaster planning during major post-earthquake rescues. The Chinese Government's response to disasters is defined by a militarily proactive and highly centralized command structure. The Chinese Government set up an earthquake relief headquarters within two hours of the Wenchuan earthquake, and the Provincial Health Department coordinated the logistics of the operation, served as a strategic base of operation, prevented shortages and inappropriate use of local resources, and ensured cooperation. Medical rescue forces from the rest of China were uniformly deployed by this department (12). A disaster medical care system that utilizes hospitals as disaster management centers was developed by the Japanese Government as a result of lessons learned from prior disasters: multiple main disaster management hospitals were established in each prefecture, one of which was assigned to each municipality (18).

In disaster scenarios, a structured triage system that is easy to implement and adhere to is key. ED is where the medical chain from diagnosis to treatment begins for all victims during a disaster; accurately evaluating patients to determine the best course of action according to their needs and then allocating available resources according to the priority of their conditions is crucial. While a rapid and accurate method of triaging patients is critical in disaster settings, there is no golden rule for deciding who receives priority treatment. According to research, even in the aftermath of the same disaster, some patients were prioritized based on their medical needs (19), while others were prioritized based on a mix of patient needs and the imperative to make the best possible use of available resources, as in the case of the 2021 Haiti earthquake (20). Most of the times, a basic triage approach (START) is employed as in the multicentered, cross-sectional study by Uz et al. (21) regarding the 2020 Aegean Sea-İzmir earthquake victims: patients are divided into four groups according to their condition: green means a minor injury that is not urgent, yellow implies a slight injury that might be delayed, red indicates a serious injury, and black indicates death. According to their findings, patients with the yellow triage code presented most frequently during the first hour, and patients with the black triage code were most often brought in after 24 hours. The majority of patients

(55%, n=103) were entrapped under debris for longer than 24 hours, and they had the highest mortality rate (21).

According to a study that provided an overview of the hospital triage procedure used for patients evaluated and treated at Sichuan University's West China Hospital, earthquake victims were assigned by an emergency professor to either an immediate treatment area, a secondary priority treatment area, or a minor treatment area based on the extent of their injury upon arrival to the ED. Their triaging system was essentially similar to that of the four groups: resuscitation or emergency treatment, urgent treatment, delayed treatment, and minor injuries (2). Depending on the severity of the injuries, waiting durations varied, which underlines the importance of correct assessment and categorization of patients, since a misassignment can significantly affect their prognosis. The same triage procedures were utilized in a hospital following the 2017 earthquake in Mexico City: administrative staff outside the hospital classified patients using a similar system-color codes of green, yellow, red, and black-to identify them. Emergency medical teams were assembled in the waiting area and included a nurse, an intern, and a resident in surgery or orthopedic trauma (5). Although the triage process may vary, it is vital to improve emergency response by assembling teams of medical professionals from different specialties to handle large-scale casualties. Nie et al. (2), reported that ED teams were established following the Sichuan earthquake, including general surgeons, orthopedic surgeons, plastic surgeons, neurosurgeons, and pediatric surgeons. A senior emergency medicine physician made the final triage decisions for each patient, and on rare occasions, the senior physicians' opinion would differ from the initial triage assessment. The final accuracy rate (1984/2229) was 89.0%, which was an acceptable ratio (2). Again, a type 3 Emergency Medical Team-which is capable of offering in-patient referral surgical surgery as well as intensive care services-was assembled within 80 hours after the earthquake in Kathmandu (22). Establishment of a well-trained, coordinated, and equipped emergency medical team is imperative in ensuring the timely diagnosis and treatment of earthquake victims. The composition and capabilities of these teams should be tailored to the local resources and needs of the affected region. However, surgically trained professionals, particularly in the fields of orthopedics and neurosurgery, should be included as their expertise can be crucial in disaster situations.

3. Injuries and Trauma Management

The primary challenge emergency health care providers encounter in an earthquake disaster situation is the presentation and management of injuries and their variety, since there are many ways that people may be hurt in an earthquake, such as being crushed by fallen debris, falling from high buildings, and being struck by flying objects. Patients should be thoroughly assessed primarily for signs of extremity fractures, internal organ damage, impaired brain function, and spinal cord injuries as these are shown to be the main findings of both life-threatening and disabling injuries following an earthquake (23). However, assessment of earthquake survivors is often impaired by the limited availability of diagnostic modalities and resources in EDs in the setting of a crowded ER during the aftermath of the disaster. According to Uz et al. (21), computed tomography (CT) and laboratory were the most frequently used resources in the first hour during the 2020 Aegean Sea earthquake, yet performing dozens of CT scans at the same time was challenging. Some patients had to be evaluated solely on a physical examination, foregoing imaging tests. Many patients received plaster splints and were discharged without undergoing any imaging modalities, such as X-ray scans and joint tomography, and were referred to outpatient clinics (21). Yitzhak et al. (22), also mentioned a lack of advanced diagnostic instruments, such as CT scans, as one of the challenges during the diagnosis and treatment of Kathmandu earthquake survivors, along with a lack of resources, insufficient intensive care unit beds, and team accommodation. These difficulties facilitate the necessity of portable units, such as portable ultrasound devices. E-FAST has been successfully used in the emergency setting following the earthquake and is an essential instrument for identifying serious injuries that may pose a serious risk of mortality (21). Besides being a quick and cost effective tool with high sensitivity and specificity for diagnosing conditions ranging from simple fluid collection in the pericardium to penetrating thoracic trauma, portable ultrasound devices are employed during several invasive operations. After the 2010 Haiti earthquake, anesthesiologists reported using a portable ultrasound scanner to perform ultrasound-guided regional anesthesia for pre-operative analgesia. This technique helped address unclear surface signs caused by trauma while providing necessary muscle relaxation (24).

While patients with multiple injuries can comprise up to 26.7%-56.7% of all individuals injured following an earthquake (25,26), the most common identifiable site of trauma was shown to be the lower extremities in multiple injury studies and across different earthquakes (4,8,23,27,28,29,30,31). Timely surgical intervention must be provided to patients with severe leg injuries that might have compromised blood flow due to compartment syndrome, hematomas, or vascular injuries. On rare occasions, amputation of injured limbs may be performed to prevent the development of sepsis and subsequent multi-organ failure. Turgut et al. (32) observed a direct correlation between the time spent under debris and the severity of compartment syndrome, the need for emergency fasciotomy, and amputations. Similar findings were reported by Tahmasebi et al. (33), who demonstrated a correlation between the incidence of compartment syndrome and the length of time spent under rubble. However, there is a disagreement among physicians over whether fasciotomy is appropriate for patients who have suffered crush injuries. To increase circulation and stop muscle necrosis, supporters of the approach claim that injured limbs should be swiftly decompressed. Others argue that the risk of infection is too high to perform the procedure in an emergency situation (34). According to Michealson (35), closed crush injuries should only be managed by fasciotomy if distal gangrene begins to develop. Likewise, there is controversy regarding the amputation of limbs in patients with Crush syndrome due to the possibility of myoglobin and potassium leakage from necrotic tissue during the procedure (36).

Immediate debridement and irrigation of dirty wounds alongside administration of antibiotics should be performed as early as possible in the ED following an earthquake. This protocol is vital in preventing wound complications such as infections and may save patients from developing systemic complications, sepsis, and even possible amputation in some circumstances. Yitzhak et al. (22) stated that orthopedic surgeries were typically conducted for wound debridement as the primary diagnosis following the 2015 Nepal earthquake. Two distinct studies also reported that wound debridement accounted for a significant fraction of the surgical procedures performed following the Pakistan earthquake (29,37). Open fractures carry a particular risk of infection and require immediate treatment starting in the ED. Antibiotics are given to prevent the development of conditions such as osteomyelitis, while stabilizing the fracture with external fixators can help to ensure proper alignment during healing and provide structural support. The mortality rate for crushing injuries with open wounds was found to be higher after the 2020 Aegean Sea-İzmir earthquake than it was for crushing injuries without open wounds (21), and the reported range of open fracture proportions during earthquakes is 32%-54% (38).

While not as frequent as limb injuries, head injuries can be highly lethal and often require urgent management in the ED. According to a review of 25 studies, the median frequency of brain injuries was 16.6%, placing them third among patients who were earthquake victims. The majority of patients with head injuries (59.1%) had contusions or lacerations, 32.3% had skull fractures, and 9.5% had epidural hematomas. The most frequent cerebral hemorrhage caused by an earthquake was epidural hematoma (23). The mean percentage of inpatients who underwent major surgery after suffering a head injury was 15.5%. Five patients who underwent craniotomies more than 90 min after the onset of anisocoria all passed away, emphasizing the significance of timely surgical intervention in individuals exhibiting symptoms. According to Aurangzeb et al. (39), single burr hole surgery is reliable and has provided positive results for many patients with earthquake-related epidural hematomas. Preventing unnecessary delays in treating patients with a suspected brain injury is crucial to the management of patients with potentially fatal intracranial injuries. Spinal cord injuries can also occur in earthquake-related trauma and should be considered as part of the initial assessment in EDs. During the Kermanshah earthquake, 120 patients were disabled and 18 patients sustained spinal cord injury (15). According to one study, mortality is the most common outcome for quadriplegics (40). The majority of spinal injuries are thoracolumbar in origin, with the lumbar spine being the most commonly damaged (41). Earthquake-related thoracic injuries have been found to be a significant predictor of mortality in some earthquakes, despite being fewer and more likely to be mild (odds ratio: 375, p=0.004) (42). In a different Chinese investigation examining the impacts of the 2008 earthquake, 21% of patients with chest injuries experienced respiratory failure, necessitating mechanical ventilation (43).

Approaches to earthquake survivors who are severely injured and require immediate assistance and treatment in the ED are contingent on a range of factors. Fractures, Crush syndrome, head and neck injuries, and abdominal and chest injuries are commonly encountered in these patients, and their treatment requires prompt recognition and swift action. Patients with head injuries must undergo immediate neuroimaging, and epidural hematomas must be managed by emergency surgical evacuation. In the presence of extremity injuries, bleeding control, wound debridement, infection prevention, and limb stabilization should be addressed. Patients with compartment syndrome should be identified early and evaluated for urgent fasciotomy or amputation. Pelvic fractures should be appropriately immobilized. Patients with chest injuries must receive early resuscitative measures, such as chest decompression and tube thoracostomy, if necessary. Regarding the need for sedation, general anesthesia was the preferred anesthetic method following the Aegean Sea earthquake (44), and ketamine was successfully used to induce and maintain anesthesia in earthquake survivors who were receiving inotropic support and had unstable hemodynamics (4). Despite the limited resources available, healthcare professionals in emergency settings need to prioritize the management of these patients and provide a coordinated approach along with surgery specialty physicians to ensure the best possible outcomes.

4. Rhabdomyolysis, Kidney Failure, and Other Complications

Trauma experienced by patients during an earthquake can lead to metabolic disorders that require prompt recognition and treatment. Hyperkalemia, hypophosphatemia, and other electrolyte disorders following rhabdomyolysis and renal function disorders are frequently encountered in earthquakes, along with secondary issues such as aggregation of chronic comorbidities and increased risk for spread of infectious diseases. These subsequent complications lead to additional morbidity and mortality, and initiating treatment of these conditions in the emergency setting is paramount.

After significant earthquakes, there is a documented frequency of 2-15% of Crush syndrome, which can be described as a crush injury with systemic complications. Acute renal failure (ARF) is thought to develop in approximately half of Crush syndrome patients, and approximately half of these individuals are reported to require dialysis (45). It is a type of traumatic rhabdomyolysis that occurs when a muscle group is subjected to prolonged, continuous pressure, which leads to severe necrosis. After the pressure on the crushed body part is released, potassium, phosphorus, and myoglobin are released from the injured areas, while calcium and sodium permeate into the necrotized muscle. Impairment of perfusion and intratubular blockage by myoglobin and uric acid cause subsequent acute renal damage. ARF, hyperkalemia, acidosis, and hypovolemic shock can all be fatal. Following the Wenchun earthquake, 41.6% of patients with Crush syndrome experienced acute kidney injury within 3 days, and 67% of those patients died, highlighting the significance and critical nature of this complication (46). Use of urine dipsticks for screening both myoglobin and rhabdomyolysis while still triaging earthquake victims is advised due to the prevalence of crush injury and its high mortality rate (42). The primary causes of death for patients with crush injuries in the first five days following an earthquake are known to be hypovolemia and hyperkalemia, which both should be addressed urgently in the ED (47), since along with oliguria they can precipitate cardiac arrhythmias and arrest (48). Systolic hypotension on admission, female sex, and peak blood creatine kinase values greater than 20.000 U/L all shown to increase the risk for mortality in patients with ARF (49). Even if a patient's vital signs initially appear normal, early, aggressive fluid resuscitation via intravenous (IV) fluids in large quantities is essential to prevent and treat ARF in the majority of crush injury patients. Rhabdomyolysis treatment consists of an initial IV fluid infusion of up to 1.5 L/h followed by IV fluid rehydration or 500 mL/h saline solution alternated every hour with a goal urine output of 200 mL/h (50). Emergency fasciotomy should be considered if compartment syndrome is the primary cause. Potassium concentrations and electrocardiography changes should be monitored frequently, and potassium-containing intravenous solutions should be avoided if possible.

ARF or severe complications of Crush syndrome in patients with crush injuries can be prevented by intensive fluid therapy, alkalinization, and forced diuresis when necessary. It has been proposed that the development of myoglobinuric ARF can be avoided if the people buried under the wreckage are rescued within the first 6 hours and treated accordingly (51). However, on some occasions, dialysis is required because of severe hyperkalemia, kidney failure that can not be managed by conventional treatment, and the necessity to address abnormalities in pH and electrolytes. Sarı et al. (31) observed that among adult survivors with Crush syndrome following the 2023 Kahramanmaraş earthquake, 26.6% only required fluid therapy, whereas 20.7% needed renal replacement therapy (hemodialysis). Rhabdomyolysis developed in 15.9% (32) of the patients who survived the 2020 Aegean Sea earthquake, and four (1.9%) of these patients underwent hemodialysis in the ER because of ARF (21). Çağıran et al. (4) reported that in the aftermath of the same earthquake, Crush syndrome/ARF developed in 8.55% (n=13) of the surviving patients, with dialysis being utilized in 1.32% (n=2). Regarding the 43,953 patients that were transferred to reference hospitals following the Marmara earthquake, 639 (1.5%) of them had renal failure, and 477 of these patients (74.6%) required hemodialysis (42). Patients with oliguric renal failure could be given the highest priority if dialysis needs to be prioritized, and those with hyperkalemia could be treated medically and renal replacement therapy could be delayed among these patients (52).

In addition to the severe traumatic injuries and injury-related health issues mentioned earlier, there are other potential short- and long-term complications and health risks that accompany the period following a major earthquake. Patients who are trapped under debris or debris for extended periods of time face significant health risks from environmental exposure, such as hypothermia. Survivors are at an elevated risk of contracting respiratory diseases such as pneumonia and influenza. Disruption of water and sanitation services, as well as contamination of food and drink, may also lead to epidemics of gastrointestinal and water-borne illnesses (53). Psychiatric disorders, including post-traumatic stress disorder, depression, and anxiety, may emerge shortly after an earthquake and may need to be evaluated and managed by emergency services. Cardiovascular diseases, such as hypertension and myocardial infarction, can also occur as a result of emotional and physical strain and difficulty in accessing patients' routine treatments.

There was a reported change in the healthcare requirements of survivors after the initial earthquake period. While the majority of injuries sustained in the aftermath of the Wenchun earthquake were traumatic in origin, upper respiratory tract infections, enteritis, and skin illnesses progressively surfaced after a week (12). The increased frequency of respiratory diseases, gastrointestinal disorders, skin issues, eye infections, and urinary tract infections was partially related to unsanitary conditions (54). While no specific disease epidemic was noted after approximately 8,000 people received diphtheria and tetanus vaccinations following the Kermanshah earthquake, the city's accumulated waste blocked the waterways and accumulated around the shelters, which led to an increase in a number of diseases, including cholera (15). In addition to environmental concerns, issues from infections following delayed presentations of earthquake-related injuries were common due to the lack of medical treatment (55,56). Following the 2005 Pakistan earthquake, many of the treated patients with extremity fractures and deploying of extremities were found to have purulent discharges three weeks later (57). Bartels and VanRooyen (58) described a third peak in deaths that occurred days to weeks after the earthquake and attributed it to sepsis, multisystem organ failure, and disseminated intravascular coagulation, stating that these patients have the greatest potential for survival. Emergent decontamination of the affected area, cleaning of wounds, and administration of antibiotics can help to prevent the spread of infectious diseases and reduce the risk of secondary bacterial infections. Studies on earthquakes in Japan, Pakistan, and Haiti have shown that increasing the number of specialists in internal medicine pediatrics and infectious diseases can reduce the complications and mortality related to delayed rescue, and collaborating with physicians of the mentioned specialties in the ED may help to provide comprehensive care for these patients (59).

Following an earthquake, an increase in patients presenting to the hospital with cardiovascular diseases and hypertensive cardiocerebral issues has been noted (60). Acute myocardial infarction (14.5% vs. 22.8%; p=0.028), elevation of blood pressure (10% vs. 21.8%, p=0.001), and paroxysmal arrhythmias treated with electrocardioversion (0.9% vs. 4.5%, p=0.022) were significantly more common in a subgroup analysis of patients treated in hospitals located within 20 km of the epicenter according to Babić et al. (61). Again, after the 1994 earthquake in California, USA, the number of patients admitted with acute myocardial infarctions increased by 35% in the week following the disaster (62). When compared with the same period in the previous year, the rate of admission for acute myocardial infarction increased considerably in the six weeks following the earthquake in Taiwan (63). Patients with high blood pressure may also have adverse outcomes from earthquakes. The mean systolic blood pressure was found to be 14-16 mmHg higher and the mean diastolic blood pressure was 6-10 mmHg higher than the baseline values in elderly patients following the 1995 earthquake in Japan (64). Earthquakes also led to an increase in the mortality of cerebrovascular diseases. The number of fatal strokes among the elderly increased in the three months following the 1995 earthquake in Japan (58 stroke deaths after the earthquake vs. 31 in the same period the previous year) (65). Increased risk of these complications post-earthquake, including cardiovascular and cerebrovascular problems, may be associated with stress (both physical and physiological), subsequent excarnation of underlying health conditions, inability to access regular medication, and poor living conditions in the aftermath of a disaster. Identifying and monitoring earthquake survivors who are at high risk for these complications, managing unregulated blood pressure issues, and performing screening and diagnostic tests such as electrocardiograms, echocardiography, and cerebral imaging modalities are all essential measures that can be implemented in the ED.

Conclusion

In conclusion, overall, the experiences from past disasters suggest that emergency services need to be better prepared for unique challenges when treating earthquake-related traumatic injuries and their complications. Improved communication, collaboration between different healthcare departments, and coordination between healthcare facilities in the immediate disaster zone can help optimize resources and minimize delays in diagnosis, treatment, and transport of patients. When imaging modalities cannot meet the demand, portable devices such as E-FAST have shown promise in helping to identify critical injuries and guide clinicians. Combined with well-established triage protocols and a dedicated team of physicians from multiple disciplines, EDs should prioritize the allocation of limited resources to ensure that patients with urgent and life-threatening injuries receive timely and appropriate care. Timely diagnosis and treatment of traumatic injuries and related conditions such as Crush syndrome and rhabdomyolysis after earthquakes are imperative to provide best chances of survival to patients. Possible later complications such as neurovascular events and infections may contribute to reduced mortality and morbidity rates and should be addressed accordingly.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: Ö.Y., S.D., A.A., Design: Ö.Y., S.D., A.A., Data Collection or Processing: Ö.Y., S.D., A.A., Analysis or Interpretation: Ö.Y., S.D., A.A., Literature Search: Ö.Y., S.D., A.A., Writing: Ö.Y., S.D., A.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Goodman A, Black L, Briggs S. Obstetrical care and women's health in the aftermath of disasters: the first 14 days after the 2010 Haitian earthquake. Am J Disaster Med 2014;9:59-65.
2. Nie H, Tang SY, Lau WB, et al. Triage during the week of the Sichuan earthquake: a review of utilized patient triage, care, and disposition procedures. Injury 2011;42:515-520.
3. Basnyat B, Tabin C, Nutt C, Farmer P. Post-earthquake Nepal: the way forward. Lancet Glob Health 2015;3:731-732.
4. Çağıran Z, Sertöz N, Karaman S, et al. Our clinical experiences in the earthquake victims who came to our university after the 2020 Aegean Sea earthquake during the COVID-19 pandemic. Ulus Travma Acil Cerrahi Derg 2023;29:310-315.
5. Arroyo-Berezowsky C, Abonce-Zenteno J. The epidemiology of patients treated at a private hospital as a consequence of the September 19th 2017 earthquake in Mexico City. Acta Ortop Mex 2020;34:215-221.
6. Ministry of Interior Disaster and Emergency Management Presidency. Press bulletin 01.03.2023 about the earthquake in Kahramanmaraş - 36. Available from: https://en.afad.gov.tr/press-bulletin-36-about-the-earthquake-in-kahramanmaras. Accessed March 2, 2023.
7. Doocy S, Jacquet G, Cherewick M, Kirsch TD. The injury burden of the 2010 Haiti earthquake: a stratified cluster survey. Injury 2013;44:842-847.
8. Ergen E, Kaya O, Yılmaz Ö, et al. Which is more dangerous, earthquake, or the panic? Evaluation of the 24 January 2020 Elazig/Türkiye earthquake related musculoskeletal injuries. Ulus Travma Acil Cerrahi Derg 2022;28:1335-1339.
9. Broach JP, McNamara M, Harrison K. Ambulatory care by disaster responders in the tent camps of Port-au-Prince, Haiti, January 2010. Disaster Med Public Health Prep 2010;4:116-121.
10. Jain V, Noponen R, Smith BM. Pediatric surgical emergencies in the setting of a natural disaster: experiences from the 2001 earthquake in Gujarat, India. J Pediatr Surg 2003;38:663-667.
11. Jacquet GA, Hansoti B, Vu A, Bayram JD. Earthquake-related injuries in the pediatric population: a systematic review. PLoS Curr 2013:5:ecurrents.
12. Ukai T. The Great Hanshin-Awaji Earthquake and the problems with emergency medical care. Ren Fail 1997;19:633-645.
13. Deng S, Zheng S, Shi Y. Applying lessons from China's Wenchuan earthquake to medical rescue following the Yushu earthquake. J Evid Based Med 2010;3:62-64.
14. Kondo H, Koido Y, Hirose Y, Kumagai K, Homma M, Henmi H. Analysis of trends and emergency activities relating to critical victims of the Chuetsuoki earthquake. Prehosp Disaster Med 2012;27:3-12.
15. Ghanjal A, Bahadori M, Ravangard R. An overview of the health services provision in the 2017 Kermanshah earthquake. Disaster Med Public Health Prep 2019;13:691-694.
16. Turkish Enterprise and Business Confederation (TURKONFED)-2023 Kahramanmaraş Earthquake-Pre-Assessment and Status Report. Available from: https://turkonfed.org/tr/detay/3937/2023-kahramanmaras-depremi-afet-on-degerlendirme-durum-raporu. Published 2023. Accessed March 4, 2023.
17. Schultz CH, Koenig KL, Lewis RJ. Decisionmaking in hospital earthquake evacuation: does distance from the epicenter matter? Ann Emerg Med 2007;50:320-326.
18. Henmi H. Report of the research about medical response system for health security and disaster. Tokyo: MHLW Health and Labour Sciences Research Grant; 2007.
19. Steinman M, Lottenberg C, Pavao OF, et al. Emergency response to the Haitian earthquake--as bad as it gets. Injury 2012;43:386-387.
20. Merin O, Miskin IN, Lin G, Wiser I, Kreiss Y. Triage in mass-casualty events: the Haitian experience. Prehosp Disaster Med 2011;26:386-390.
21. Uz İ, Çetin M, Songur Kodik M, Güvenç E, Karbek Akarca F, Ersel M. Emergency department management after the 2020 Aegean Sea - Izmir earthquake. Ulus Travma Acil Cerrahi Derg 2022;28:361-368.
22. Yitzhak A, Merin O, Halevy J, Tarif B. Emergency with resiliency equals efficiency - challenges of an EMT-3 in Nepal. Prehosp Disaster Med 2018;33:673-677.
23. Igarashi Y, Matsumoto N, Kubo T, et al. Prevalence and characteristics of earthquake-related head injuries: a systematic review. Disaster Med Public Health Prep 2022;16:1253-1258.
24. Shah S, Dalal A, Smith RM, Joseph G, Rogers S, Dyer GS. Impact of portable ultrasound in trauma care after the Haitian earthquake of 2010. Am J Emerg Med 2010;28:970-971.

25. Bhatti SH, Ahmed I, Qureshi NA, Akram M, Khan J. Head trauma due to earthquake October, 2005-experience of 300 cases at the Combined Military Hospital Rawalpindi. J Coll Physicians Surg Pak 2008;18:22-26.
26. Zheng X, Hu Y, Yuan Y, Zhao YF. Retrospective cohort analysis of chest injury characteristics and concurrent injuries in patients admitted to hospital in the Wenchuan and Lushan earthquakes in Sichuan, China. PLoS One 2014;9:e97354.
27. Roy N, Shah H, Patel V, Bagalkote H. Surgical and psychosocial outcomes in the rural injured--a follow-up study of the 2001 earthquake victims. Injury 2005;36:927-934.
28. Teicher CL, Alberti K, Porten K, Elder G, Baron E, Herard P. Médecins sans frontières experience in orthopedic surgery in postearthquake Haiti in 2010. Prehosp Disaster Med 2014;29:21-26.
29. Ahmad MA, Naqui SZ, Shah N, Khan A, Alexander-Williams JM, Jaffery A. The Pakistan earthquake: a British trainee's experience. Injury 2006;37:567-569.
30. Demirkiran O, Dikmen Y, Utku T, Urkmez S. Crush syndrome patients after the Marmara earthquake. Emerg Med J 2003;20:247-250.
31. Sarı H, Özel M, Akkoç MF, Şen A. First-Week Analysis after the Turkey earthquakes: demographic and clinical outcomes of victims. Prehosp Disaster Med 2023;38:294-300.
32. Turgut N, Adaş G, Akçakaya A, Mıngır T, Topuz C, Ay A. Earthquake; trauma, Crush syndrome and cardiopulmonary resuscitation. Eur Arc Med Res 2012;28(Suppl 2):135-147.
33. Tahmasebi MN, Kiani K, Mazlouman SJ, et al. Musculoskeletal injuries associated with earthquake: A report of injuries of Iran's December 26, 2003 Bam earthquake casualties managed in tertiary referral centers. Injury 2005;36:27-32.
34. Duman H, Kulahci Y, Sengezer M. Fasciotomy in crush injury resulting from prolonged pressure in an earthquake in Turkey. Emerg Med J 2003;20:251-252.
35. Michealson M. Crush injury and Crush syndrome. World J Surg 1992;16:899-903.
36. Malinoski DJ, Slater MS, Mullins RJ. Crush injury and rhabdomyolysis. Crit Care Clin 2004;20:171-192.
37. Awais SM, Dar UZ, Saeed A. Amputations of limbs during the 2005 earthquake in Pakistan: a firsthand experience of the author. Int Orthop 2012;36:2323-2326.
38. Liu L, Tang X, Pei FX, et al. Treatment for 332 cases of lower leg fracture in "5.12" Wenchuan earthquake. Chin J Traumatol 2010;13:10-14.
39. Aurangzeb A, Ahmed E, Maqbool S, et al. Burr hole evacuation of extradural hematoma in mass trauma. A life saving and time saving procedure: our experience in the earthquake of 2005. Turk Neurosurg 2016;26:205-208.
40. Rathore FA. Revisiting the 2005 earthquake paraplegics: what has changed in a decade? J Ayub Med Coll Abbottabad 2015;27:513-514.
41. Li T, Zhou C, Liu L, et al. Analysis of spinal injuries in Wenchyan earthquake. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2009;23:415-418.
42. Sever MS, Erek E, Vanholder R, et al. Treatment modalities and outcome of the renal victims of the Marmara earthquake. Nephron 2002;92:64-71.
43. Hu Y, Tang Y, Yuan Y, Xie TP, Zhao YF. Trauma evaluation of patients with chest injury in the 2008 earthquake of Wenchuan, Sechuan, China. World J Surg 2010;34:728-732.
44. Missair A, Pretto EA, Visan A, et al. A matter of life or limb? A review of traumatic injury patterns and anesthesia techniques for disaster relief after major earthquakes. Anesth Analg 2013;117:934-941.
45. Briggs SM. Earthquakes. Surg Clin North Am 2006;86:537-544.
46. He Q, Wang F, Li G, et al. Crush syndrome and acute kidney injury in the Wenchuan earthquake. J Trauma 2011;70:1213-1217.
47. Oda J, Tanaka H, Yoshioka T, et al. Analysis of 372 patients with Crush syndrome caused by the Hanshin-Awaji earthquake. J Trauma 1997;42:470-476.
48. Jagodzinski NA, Weerasinghe C, Porter K. Crush injuries and Crush syndrome-a review. Part 1: the systemic injury. Trauma 2010;12:69-88.
49. Ersoy A, Yavuz M, Usta M, et al. Survival analysis of the factors affecting in mortality in injured patients requiring dialysis due to acute renal failure during the Marmara earthquake: survivors vs non-survivors. Clin Nephrol 2003;59:334-340.
50. Torres PA, Helmstetter JA, Kaye AM, Kaye AD. Rhabdomyolysis: pathogenesis, diagnosis, and treatment. Ochsner J 2015;15:58-69.
51. Better OS. Acute renal failure in casulties of mass disasters. Kidney Int Suppl 1993;41:235-236.
52. Amundson D, Dadekian G, Etienne M, et al. Practicing internal medicine onboard the USNS COMFORT in the aftermath of the Haitian earthquake. Ann Intern Med 2010;152:733-737.
53. Watson JT, Gayer M, Connolly MA. Epidemics after natural disasters. Emerg Infect Dis 2007;13:1-5.
54. van Berlaer G, Staes T, Danschutter D, et al. Disaster preparedness and response improvement: comparison of the 2010 Haiti earthquake-related diagnoses with baseline medical data. Eur J Emerg Med 2017;24:382-388.
55. Bayard D. Haiti earthquake relief, phase two--long-term needs and local resources. N Engl J Med 2010;362:1858-1861.
56. Sami F, Ali F, Zaidi SH, Rehman H, Ahmad T, Siddiqui MI. The October 2005 earthquake in Northern Pakistan: patterns of injuries in victims brought to the Emergency Relief Hospital, Doraha, Mansehra. Prehosp Disaster Med 2009;24:535-539.
57. Ahmad MA, Naqui SZ, Shah N, Khan A, Alexander-Williams JM, Jaffery A. The Pakistan earthquake: a British trainee's experience. Injury. 2006;37:567-569.
58. Bartels SA, VanRooyen MJ. Medical complications associated with earthquakes. Lancet 2012;379:748-757.
59. Miller AC, Arquilla B. Chronic diseases and natural hazards: impact of disasters on diabetic, renal, and cardiac patients. Prehosp Disaster Med 2008;23:185-194.
60. Beinin L. Public health consequences of earthquakes in medical consequences of natural disasters. Berlin: Springer Verlag; 1985, pp. 12-27.
61. Babić Z, Pavlov M, Radić P, et al. The impact of earthquakes on the frequency and prognosis of the most common emergency cardiac conditions. Croat Med J 2023;64:164-169.

62. Kloner RA. Natural and unnatural triggers of myocardial infarction. Prog Cardiovasc Dis 2006;48:285-300.
63. Tsai CH, Lung FW, Wang SY. The 1999 Ji-Ji (Taiwan) earthquake as a trigger for acute myocardial infarction. Psychosomatics 2004;45:477-482.
64. Kario K, Matsuo T, Shimada K, Pickering TG. Factors associated with the occurrence and magnitude of earthquake-induced increases in blood pressure. Am J Med 2001;111:379-384.
65. Kario K, Ohashi T. After a major earthquake, stroke death occurs more frequently than coronary heart disease in very old subjects. J Am Geriatr Soc 1998;46:537-538.

REVIEW

DOI: 10.4274/csmedj.galenos.2023.2023-9-1

Cam and Sakura Med J 2023;3(Suppl 1):14-18

CSMJ

CAM & SAKURA MEDICAL JOURNAL

Orthopaedic Triage and Management of Earthquake Victims

Güzelali Özdemir, Olgun Bingöl, Enver Kılıç

Ankara Bilkent City Hospital, Clinic of Orthopaedics and Traumatology, Ankara, Turkey

ABSTRACT

Major earthquakes can cause crush injuries. Damage to buildings is a major cause of death and injury in earthquakes, especially when solid building materials such as concrete are used. The most common injuries following earthquakes are fractures, compartment syndromes, major soft tissue injuries, and crush injuries. This highlights the importance of planning at the national level before natural disasters occur. The aim of this study was to review what needs to be done in orthopedic and trauma services in the field, during transfer, and in advanced treatment centers after an earthquake disaster in our country, where high-intensity earthquakes occur. In conclusion, strategic planning in the field, during transfer, and in advanced treatment centers can reduce the pressure on the health system in similar mass disasters.

Keywords: Orthopaedic triage, earthquake, victims, management

Introduction

The region in which Turkey is located is one of the most active tectonic regions on earth. Many large and small earthquakes have occurred in our country throughout history. New earthquakes are expected to occur in our region in the future. Measures should be taken against the destructive effects of these earthquakes. However, rescue and health services should also be organized after an earthquake.

Major earthquakes can cause crush injuries. Damage to buildings is a major cause of death and injury in earthquakes, especially when solid building materials such as concrete are used. Earthquakes also cause damage to infrastructure, health facilities, and transport (1).

The most common injuries following earthquakes are fractures, compartment syndromes, major soft tissue injuries, and crush injuries (2). Therefore, patients admitted to healthcare facilities are more likely to have extremity injuries than non-orthopaedic injuries (3). Most orthopedic injuries are fractures, and most fractures after the earthquake occurred in the diaphyseal region of the tibia and femur (1). The high number of orthopedic cases observed in previous studies emphasizes the need for orthopedic surgery in natural disaster and conflict settings (2,3,4).

Previous studies have confirmed the existence of organizational and educational barriers to quality surgical care following the Haiti earthquake (5,6,7). This highlights the importance of national planning before natural disasters to prevent patient overload and provide advanced life support.

Address for Correspondence: Assoc. Prof. Güzelali Özdemir, Ankara Bilkent City Hospital, Clinic of Orthopaedics and Traumatology, Ankara, Turkey

Phone: +90 532 584 36 11 **E-mail:** drguzelali@yahoo.com **ORCID ID:** orcid.org/0000-0003-4279-0955

Received: 02.09.2023 **Accepted:** 12.12.2023

The aim of this study was to review what needs to be done in orthopedic and traumatological services in the field, during transfer, and in advanced treatment centers after an earthquake disaster in our country, where high-intensity earthquakes occur.

In the Field

After an earthquake, the work capacity of health workers should be assessed quickly. Healthcare workers may also be disaster victims because of physical and psychological losses (8). In this case, the authorities should be informed quickly, and backup staff should be available if needed. Several emergency teams should be formed before the disaster, and they should be prepared in advance for their roles in disaster response scenarios.

Healthcare workers should ensure their own safety before rescuing survivors from the rubble of the disaster site. This is because the loss of healthcare workers will adversely affect the response. The removal of survivors should therefore be left to specialist rescue teams (9).

The maximum survival time in a trap is an important issue for rescuers. After reviewing the literature, Macintyre et al. (9) concluded that numerous survivors have survived entrapments for more than 48 hours, with a few successfully surviving entrapments for 13-14 days.

Assessment of casualties should be performed using the Advanced Trauma Life Support System, with a two-stage assessment recommended. The primary approach is to quickly identify life-threatening injuries. A detailed secondary approach is required for a more accurate assessment. Survival of casualties recovered from under the rubble depends on early medical intervention by emergency teams at the scene. Treatment of casualties trapped under the rubble should begin as soon as communication is established (10). Early intervention should include basic life support, prevention of blood loss, stabilization of fractures, prevention of hypothermia, and fluid therapy.

It is recommended that isotonic sodium chloride (NaCl) be used as the most readily available liquid in the field. Potassium-containing solutions should be strictly avoided. Inappropriate fluid replacement increases the risk of developing acute kidney injury after crush injury (11). Non-steroidal anti-inflammatory drugs should not be preferred for pain relief. Narcotics should also be used for pain relief.

In cases of mass casualties, the injured should be reached as soon as possible and the most appropriate intervention should be made. In such cases, institutions and individual critical care providers must use a moral framework to allocate available resources efficiently and fairly. Therefore, guidelines for the triage of critically ill patients are presented (12,13,14,15). The importance of field triage in the scene of an incident has been demonstrated previously. In a mass casualty incident, field triage should be performed by the first medical team arriving at the scene. Subsequent healthcare teams should provide medical interventions to the casualties. Conveniently, there are five classifications with corresponding colors (Table 1) (16).

Alvarado et al. (4) described seven basic requirements for surgical care in the field (Table 2). Basic orthopedic procedures could be performed in these settings. However, more demanding procedures, such as internal fixation, can only be performed at certain sites. These requirements are increased when internal fixation procedures are performed; 1) improved air quality with filters; 2) availability of water supply in quantity and quality; 3) special orthopaedic accessories table, C-arm, and disposable gowns and drapes; 4) enforced dress code and procedures, use of hydro-alcoholic solutions and surface disinfectants; 5) clearly defined and dirty circuits in sterilization, autoclave, and instrument disinfectants; 6) qualified orthopaedic surgeons, nurses and infection control

Table 1. Triage classification by color

1	Black/expectant	They are so badly injured that they will die from their injuries, possibly within hours. Treatment is usually palliative, such as administering painkillers to reduce suffering.
2	Red/immediate	Immediate surgery or other life-saving intervention. Priority for surgical teams or transport to advanced facilities. Likely to survive with immediate treatment.
3	Yellow/observation	The condition is stable for the moment but requires observation by trained staff and frequent reassessment. Requires hospital care.
4	Green/wait	May need medical attention in a few hours, but not immediately. Can wait several hours. Broken bones without compound fractures and many soft tissue injuries.
5	White/dismiss	Minor injuries: first aid and home care are sufficient. Medical attention is not required.

Table 2. Basic requirements for surgical care in the field

1	Adequate infrastructure, including protection from the external environment and appropriate electricity and lighting
2	Adequate provision of water and sanitation facilities
3	The availability of all essential disposable items, drugs, and equipment
4	Strict adherence to the requirements of hygiene and the universal precautionary principle
5	Mandatory use of sterile equipment for surgical and anaesthetic procedures
6	Blood transfusion capability
7	Adequate human resources in terms of quantity and quality

officers, physiotherapists; and 7) availability of antibiotic culture and susceptibility (4).

In some natural disasters, this organization may not be fully in place. In this case, more limited interventions, such as external fixation and referral of the injured, may be required (17,18,19). The focus of medical care should be on hemorrhage management, wound debridement, infection control, and soft tissue stabilization (2).

Great care must be taken when deciding whether to perform fasciotomy in patients who have been removed from the rubble. These patients are predisposed to acute renal failure due to rhabdomyolysis, infection, and bleeding due to Crush syndrome. Therefore, fasciotomy should not be routinely performed. Each patient should be assessed individually, and a decision should be made accordingly.

The later fasciotomy is performed, the less beneficial it is. When performed early, the need for subsequent amputation and the risk of long-term damage are lower (20,21). Delayed fasciotomy performed after 45.5 hours increase the need for amputation by 28.48 times (22).

Amputation can be lifesaving in some cases. Amputation is not a routine procedure. In the presence of crushed limbs, severe infection, and life-threatening sepsis, amputation should be performed to save the patient's life. Each patient should be assessed individually. After the 2023 Kahramanmaraş earthquakes, Bingol et al. (22) concluded that patients with extrication times longer than 23 hours were associated with an 8.8 times higher risk of amputation.

During Transfer

Patients should be taken to the hospital as soon as their general condition has stabilized in the field. In cases where advanced interventions and medical care cannot be continued, casualties should be immediately transferred to advanced treatment centers. All available air, land, and sea vehicles should be used to transport casualties. Patients for whom loss of time increases the risk of loss of life and organs should be transported by air or helicopter for rapid transfer. At this point, national coordination must ensure that the casualties receive definitive treatment. Special transport and coordination teams should be established.

Medical care should continue while the casualties are being transported. It is essential that patients continue to receive adequate fluid replacement during transport.

At Advanced Treatment Centers

From the moment the earthquake struck, hospitals with referral centers should have started preparations. All elective patients in stable condition should be discharged, and rooms should be opened for patients expected to be referred. All trauma teams should be activated in a coordinated manner. By informing medical companies, the necessary implants for emergency treatment, such as external fixators, were made available.

In the aftermath of the earthquake, the services of many clinics are needed because of the large number of injured and polytrauma cases involving many systems. The effectiveness of the multidisciplinary approach has been demonstrated in military treatment, and coordination of these teams is also important in earthquakes (23,24).

Rigal (25), in a study of disaster situations, reported that when several casualties are transferred at the same time, the treatment of patients can be delayed. It may be better to divide orthopedic and trauma surgeons into several teams and work in shifts (24). In this way, delays for treating casualties could be avoided.

Triage should be performed both in the hospital emergency department (ED) and in the field. All fractures that do not require emergency surgical treatment should be splinted, or cast, and patients with Crush syndrome should be given priority. All patients with Crush syndrome should be managed by a dedicated team of internal medicine specialists from admission to the ED until discharge (24).

During this period, the use of social networks plays a crucial role in facilitating communication (26). However, in many major disasters, communication failures have led to inadequate management (27). Precautions should be taken and preparations made. The use of social networks has several advantages. Faster treatment of patients, pre-operative and intraoperative communication between different trauma teams, and easy documentation of patient information have been achieved. In addition, patients requiring urgent intervention should not be delayed in reaching operating theatres or intensive care units (ICU) (24).

Hadary et al. (28) concluded that most of the workload in general surgery shifts from the operating room to the ED, while orthopedic procedures and ICU beds become bottlenecks in patient flow during war. In the 2023 Kahramanmaraş earthquakes, the most injured body regions were the extremities; therefore, the workload of the orthopedic and traumatology clinic was very high.

Human and material resources were limited during peak hours. Early reinforcement of the surgical staff has improved outcomes (26). Departments with high workloads, such as orthopedics and traumatology, should be augmented by health professionals from other departments (24).

Hyperbaric oxygen therapy (HBOT) is used in patients with crush injuries. However, the effectiveness of HBOT remains controversial. While some claim that it is beneficial, there are also those who report that it has no effect on clinical outcomes (29,30). Therefore, larger studies are needed to evaluate the effect of HBOT in high-energy trauma, such as earthquakes, with more muscle necrosis (30).

Different types of wounds can occur after earthquakes, and chronic wound care is also very important. Methods such as negative pressure wound therapy, debridement, collagenase creams, antiseptics, and HBOT can provide satisfactory short-term results (29).

Patients with amputations and/or completed definitive treatment should be transferred to the physical medicine and rehabilitation department. In addition, the psychiatric team should provide therapy to all patients throughout the process. This phase of treatment can take a long time. They are also very important.

Conclusion

Strategic planning in the field, during transfer, and at the advanced treatment center can reduce the burden on the health system in similar mass casualty events in the future.

An appropriate management plan should be developed and planned using a multidisciplinary approach to prevent limb loss and reduce the risk to patient life.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: G.Ö., Design: G.Ö., Data Collection or Processing: O.B., Analysis or Interpretation: E.K., Literature Search: O.B., Writing: G.Ö., O.B., E.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Ramirez M, Peek-Asa C. Epidemiology of traumatic injuries from earthquakes. Epidemiol Rev 2005;27:47-55.
2. MacKenzie JS, Banskota B, Sirisreetreerux N, Shafiq B, Hasenboehler EA. A review of the epidemiology and treatment of orthopaedic injuries after earthquakes in developing countries. World J Emerg Surg 2017;12:9.
3. Missair A, Pretto EA, Visan A, et al. A matter of life or limb? A review of traumatic injury patterns and anesthesia techniques for disaster relief after major earthquakes. Anesth Analg 2013;117:934-941.
4. Alvarado O, Trelles M, Tayler-Smith K, et al. Orthopaedic surgery in natural disaster and conflict settings: how can quality care be ensured? Int Orthop 2015;39:1901-1908.
5. Bayard D. Haiti earthquake relief, phase two--long-term needs and local resources. N Engl J Med 2010;362:1858-1861.
6. Benjamin E, Bassily-Marcus AM, Babu E, Silver L, Martin ML. Principles and practice of disaster relief: lessons from Haiti. Mt Sinai J Med 2011;78:306-318.
7. Pape JW, Johnson WD Jr, Fitzgerald DW. The earthquake in Haiti--dispatch from Port-au-Prince. N Engl J Med 2010;362:575-577.
8. Uemoto M, Inui A, Kasuga M, Shindo S, Taniguchi H. Medical staff suffered severe stress after earthquake in Kobe, Japan. BMJ 1996;313:1144.
9. Macintyre AG, Barbera JA, Smith ER. Surviving collapsed structure entrapment after earthquakes: a “time-to-rescue” analysis. Prehosp Disaster Med 2006;21:4-17.
10. Ashkenazi I, Isakovich B, Kluger Y, Alfici R, Kessel B, Better OS. Prehospital management of earthquake casualties buried under rubble. Prehosp Disaster Med 2005;20:122-133.

11. Reis ND, Michaelson M. Crush injury to the lower limbs. Treatment of the local injury. J Bone Joint Surg Am 1986;68:414-418.
12. Orban JC, Quintard H, Ichai C. ICU specialists facing terrorist attack: the Nice experience. Intensive Care Med 2017;43:683-685.
13. Kholeif A, Elnahal W, Gobba M. The orthopaedic experience of Kasr Al Ainy Hospitals in the Egyptian revolution. Eur J Trauma Emerg Surg 2016;42:97-100.
14. Mukhtar A, Hasanin A, El-Adawy A, et al. The Friday of rage of the Egyptian revolution: a unique role for anesthesiologists. Anesth Analg 2012;114:862-865.
15. Consensus statement on the triage of critically ill patients. Society of Critical Care Medicine Ethics Committee. Available from: https://pubmed.ncbi.nlm.nih.gov/7818629/
16. Mehta S. Disaster and mass casualty management in a hospital: how well are we prepared? J Postgrad Med 2006;52:89-90.
17. Hinsenkamp M. SICOT contribution to natural disaster assistance: the external fixator. Int Orthop 2014;38:1549-1550.
18. Boillot F, Herard P. External fixators and sudden-onset disasters: Médecins Sans Frontières experience. Int Orthop 2014;38:1551-1554.
19. Bertol MJ, Van Den Bergh R, Trelles Centurion M, et al. Saving life and limb: limb salvage using external fixation, a multi-centre review of orthopaedic surgical activities in Médecins Sans Frontières. Int Orthop 2014;38:1555-1561.
20. Reis ND, Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome: with special reference to earthquake casualties. J Bone Joint Surg Br 2005;87:450-453.
21. Malinoski DJ, Slater MS, Mullins RJ. Crush injury and rhabdomyolysis. Crit Care Clin 2004;20:171-192.
22. Bingol O, Karlidag T, Keskin OH, Kilic E, Sarikaya B, Ozdemir G. Preventing extremity amputations after earthquakes: a quantitative analysis of fasciotomy and extrication time. Eur J Trauma Emerg Surg 2023.
23. Elster EA, Pearl JP, DeNobile JW, et al. Transforming an academic military treatment facility into a trauma center: lessons learned from Operation Iraqi Freedom. Eplasty 2009;9:e31.
24. Özdemir G, Karlıdağ T, Bingöl O, Systematic triage and treatment of earthquake victims: Our experience in a tertiary hospital after the 2023 Kahramanmaras earthquake. Jt Dis Relat Surg 2023;34:480-487.
25. Rigal S. Extremity amputation: how to face challenging problems in a precarious environment. Int Orthop 2012;36:1989-1993.
26. Gregory TM, Bihel T, Guigui P, et al. Terrorist attacks in Paris: Surgical trauma experience in a referral center. Injury 2016;47:2122-2126.
27. De Cauwer H, Barten D, Willems M, Van der Mieren G, Somville F. Communication failure in the prehospital response to major terrorist attacks: lessons learned and future directions. Eur J Trauma Emerg Surg 2023;49:1741-1750.
28. Hadary A, Schecter W, Embon OM, Einav S. Impact of military conflict on a civilian receiving hospital in a war zone. Ann Surg 2009;249:502-509.
29. Ulusoy S, Kılınç İ, Oruç M, et al. Analysis of wound types and wound care methods after the 2023 Kahramanmaras earthquake. Jt Dis Relat Surg 2023;34:488-496.
30. Kilic E, Bingol O, Durgal A, Karlidag T, Keskin OH, Ozdemir G. Hyperbaric oxygen therapy does not change the amputation level in patients with fasciotomy after an earthquake: Our single-center experience after 2023 Kahramanmaras earthquake. Jt Dis Relat Surg 2023;34:516-522.

DOI: 10.4274/csmedj.galenos.2023.2023-9-5
Cam and Sakura Med J 2023;3(Suppl 1):19-24

CSMJ

Treatment and Follow-up for Earthquake Victims in the Intensive Care Unit

Arzu Yıldırım Ar, Yıldız Yiğit

University of Health Sciences Turkey, Fatih Sultan Mehmet Training and Research Hospital, Clinic of Anesthesiology and Reanimation, İstanbul, Turkey

ABSTRACT

Our world has been afflicted by natural disasters numerous times throughout the ages, and consequently, several morbidities and mortality have been reported. Earthquakes are natural disasters with widespread and long-lasting effects on the affected population and different clinical complications. Crush syndrome (CS) is observed in most patients followed up in the intensive care unit (ICU) after earthquakes. In CS, traumatic rhabdomyolysis, hypotension due to decreased fluid volume in the intravascular space, hyperkalemia, and renal failure due to hypovolemia can ensue. Rhabdomyolysis releases intracellular potassium, phosphorus, nucleic acids, and myoglobin into the circulation. The most important laboratory finding was hyperkalemia. Acute renal failure, compartment syndrome, disseminated intravascular coagulation, and metabolic disorders may be observed because of rhabdomyolysis. Pulmonary complications, infections, and other medical complications may develop in patients with CS. It is important to start treatment at the site of trauma before reaching the hospital, to closely monitor the patient during treatment in the ICU, and to treat patients with a multidisciplinary approach to reduce mortality and morbidity after earthquakes.

Keywords: Anesthesiology and reanimation, Crush syndrome, earthquake, intensive care unit

Introduction

Our world has been afflicted by natural disasters numerous times throughout the ages and consequently has suffered materially and psychologically (1). Several definitions summarize the wide-ranging effects of disasters. The World Health Organization defines disaster as an event that causes suffering at a level to a society exceeding its capacity to cope and disrupts normal functioning. The common point of the different definitions is that a disaster disrupts normal functioning and causes suffering and losses that exceed the coping capacity of a region (2). Earthquakes are major natural disasters that cause a range of widespread and long-lasting effects on the affected population, from injuries and infectious diseases in the acute period to disability and diseases such as anxiety and depression affecting mental health (3). The provision of appropriate care to critically ill patients in disaster situations is of vital importance. In intensive care unit (ICU) practice, it is important to define critical patients and to recognize and identify patients who will be prioritized for admission to the ICU to minimize patient mortality during both resuscitation and treatment. It is important to determine the emergency status of patients for admission to the ICU according to acute needs and risk levels. Disease severity, functional status, comorbidities, age, and other factors are important in the decision for

CAM & SAKURA MEDICAL JOURNAL

Address for Correspondence: Arzu Yıldırım Ar MD, University of Health Sciences Turkey, Fatih Sultan Mehmet Training and Research Hospital, Clinic of Anesthesiology and Reanimation, İstanbul, Turkey
Phone: +90 505 382 27 29 **E-mail:** dr.arzuyildirim@hotmail.com **ORCID ID:** orcid.org/0000-0002-5867-0897
Received: 18.09.2023 **Accepted:** 12.12.2023

admission. The Society of Critical Care Medicine admission, discharge, and triage guidelines recommend hospitalization of patients admitted to the ICU according to 2 priority levels (4). Higher priority is given to patients who require active life support for organ failure, including mechanical ventilation vasopressor invasive hemodynamic monitoring, and other similar treatments. This priority level includes patients requiring critical care such as continuous renal replacement therapies, extracorporeal membrane oxygenation, and intra-aortic balloon pumps, as well as patients with high urgency who have not yet developed organ failure. Lower priority patients include those with a significantly lower likelihood of recovery and those with advanced malignancy or chronic advanced organ failure (e.g. patients with metastatic cancer and respiratory failure secondary to pneumonia or septic shock requiring vasopressors).

In the immediate period following earthquakes, some disaster victims die in the disaster area because of the trauma suffered. Other victims die in the early and late periods depending on the degree and localization of the injury. Some are rescued and continue their treatment in the hospital. It is important that the treatment of earthquake victims starts at the site of the disaster. Prevention of metabolic acidosis and resulting hyperpotassemia is of vital importance for the survival of earthquake victims (5). Older age, admission to the ICU, severe traumatic brain injury, crush syndrome (CS), multiple organ failure and presence of cardiac/respiratory disease are known factors associated with the risk of mortality in patients hospitalized after an earthquake (6). The Injury Severity Score (ISS) has been used after disasters to define the severity of earthquake trauma. According to the ISS scoring, scores between 1 and 24 indicate mild to moderate injuries, scores between 25 and 75 indicate serious injuries, and a score of 76 indicates a fatal injury (5). After earthquakes, the types of trauma can differ depending on the infrastructural characteristics of the affected region. Different types of traumas, such as laceration, contusion, extremity, thorax, or closed abdomen traumas, can be observed. CS has been very frequently reported after the Marmara earthquake (7).

Crush Syndrome

Crush literally means compressing, being compressed, getting stuck, or being under pressure. Although these definitions only refer to the trauma itself, CS is a complex clinical state with muscle destruction (rhabdomyolysis) that occurs as a result of this trauma and surgical or medical signs and symptoms that develop afterward (1). In our country, 17,479 people died after the Marmara earthquake, and acute renal failure (ARF) developed in 639 of the 43,953 injured due to crush injury (1,8). In both the Marmara earthquake and the great Turkey-Syria earthquake that occurred in 2023, it was determined that the highest mortality rate occurred in patients who developed CS (1,9). Crush syndrome after the rescue of disaster victims and the reperfusion of destroyed muscle cells that release substances into the systemic circulation with toxic effects on the other organs (10,11). The pathophysiology of CS occurs in 2 stages. The first stage is traumatic rhabdomyolysis or muscle cell destruction. In the second stage, hypotension, hyperkalemia, and renal failure resulting from the loss of fluids in the intracellular space and metabolic events following the release of muscle cell contents to the extracellular space ensue. In addition to the damage from volume deficiency, renal injury from rhabdomyolysis is the basic component of CS (12).

Different clinical presentations can be observed before and after admission to the ICU. The clinical presentations of CS can be analyzed in two components: local symptoms in the crushed muscles and systemic findings due to the substances released from these muscles. In the early period, compartment syndrome may be observed, especially in patients who receive intensive fluid therapy before admission to the hospital, while under debris, because of increased fluid passage into the damaged muscle groups. Newly occurring swellings may develop over the course of treatment in areas that were observed to be normal before admission to the hospital/ICU. This is also a sign of an increased risk of rhabdomyolysis. The findings of compartment syndrome can be summarized with the 6P signs of ischemia: pain, pressure, paresthesia, pulselessness, paresis, and pallor that may be observed in the limb under trauma (11,13). Different substances are released into the circulation in CS, with different effects on the body. A summary of the effects of the released substances is shown in Figure 1. Systemic findings vary according to the affected organ. The most common findings are hypotension/shock, cardiac and respiratory failure, and acute renal failure (ARF). ARF observed in these patients is more complicated than that observed due to other etiologies, with high morbidity and mortality resulting from both surgical and medical complications. Although the classical triad of symptoms of rhabdomyolysis is defined as weakness, myalgia, and tea-colored urine, this triad is observed in only 10% of all patients (14). In addition to these symptoms, non-specific findings may accompany rhabdomyolysis.

Intracellular potassium, phosphorus, nucleic acids, and myoglobin pass into the circulation because of rhabdomyolysis seen in CS. The most important laboratory finding was hyperpotassemia. The resulting arrhythmia

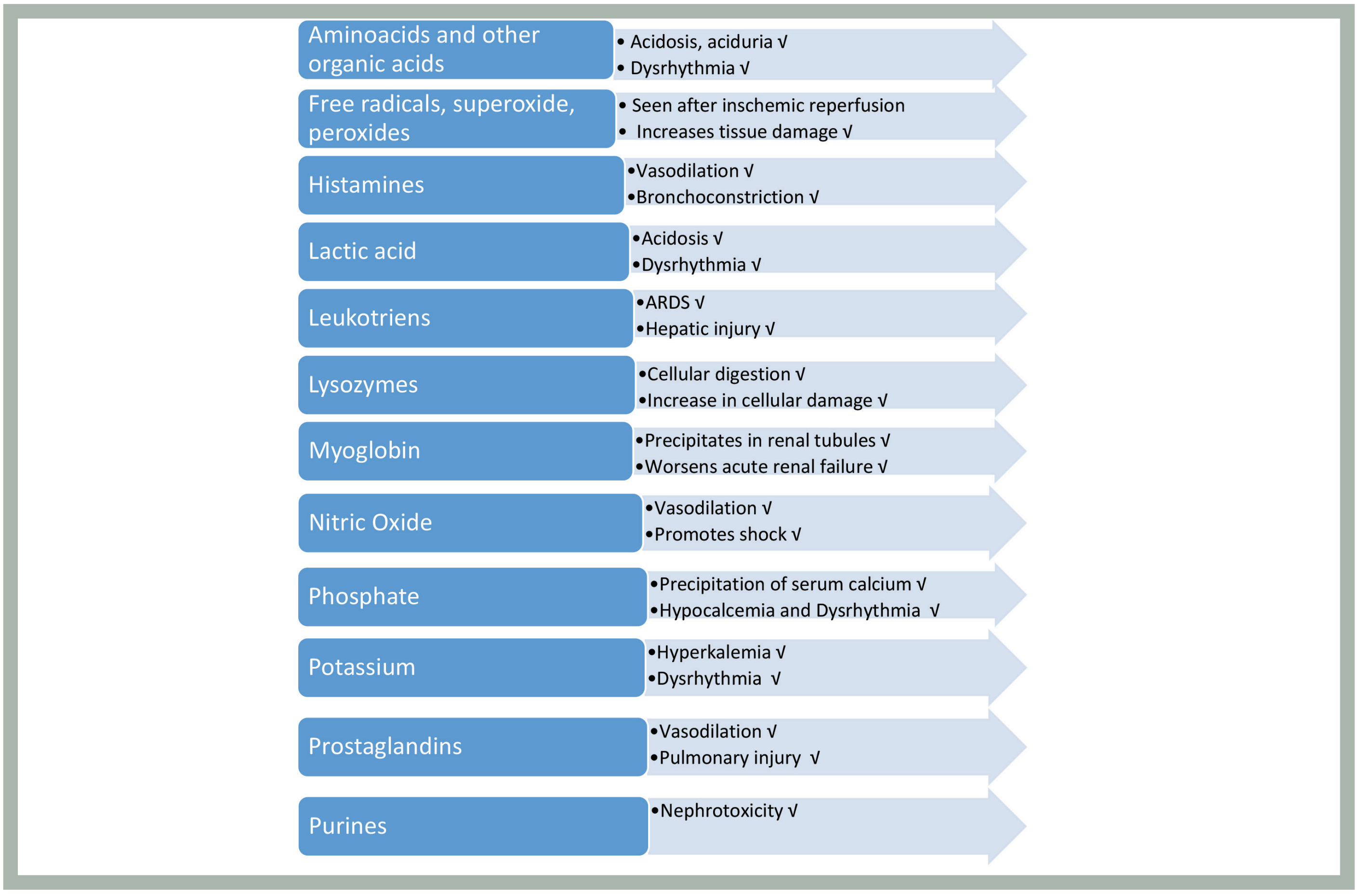


Figure 1. Systemic effects of substances released during Crush syndrome (5)

and heart failure are one of the most common causes of death. Hypocalcemia occurs as a result of the precipitation of released phosphorus and calcium crystals precipitating in soft tissues. Blood myoglobin values may be normal because of its short half-life, but they cause darkening in urine color, which we describe as cola-colored or dark red urine, and pigmented granular silt in urine sediment. Increased serum creatine kinase and lactate dehydrogenase (LDH) levels are signs of rhabdomyolysis. A correlation exists between creatine kinase levels and the degree of muscle damage. Anemia, leukocytosis, and thrombocytopenia are frequently observed. Anemia indicates traumatic bleeding or hemodilution, and leukocytosis indicates rhabdomyolysis and infections (10,15,16). In blood gas analysis, metabolic acidosis with an anion gap is often observed. Acute kidney injury (AKI) manifests as elevated serum urea and creatinine levels in patients with CS. Serum creatinine levels rise more rapidly than those in other renal pathologies. Serum creatine kinase (>5 times the upper limit of normal or >1000 IU/L), myoglobin, LDH, potassium, creatinine, and aspartate aminotransferase levels were elevated during rhabdomyolysis during ICU follow-up. Serial creatine kinase measurements are important in patient follow-up, where peak concentrations are generally reached at 24-72 hours. Follow-up of creatine kinase can be stopped when a safe downward trend is observed (17,18). For treating rhabdomyolysis, early and etiology-directed treatment is important in terms of preventing the development of ARF, preventing extremity loss, and preventing life-threatening complications (Table 1).

Table 1. Complications due to rhabdomyolysis

Mechanical complications
Peripheral neuropathy
Compartment syndrome
Acute renal failure
Disseminated intravascular coagulation
Metabolic irregularities
Hyperkalemia
Hyperuricemia
Hyperphosphatemia
Hypercalcemia (late period)
Hypocalcemia
Hypophosphatemia (late period)

Table 2. Acute kidney injury kidney disease improving global outcomes classification

	Serum creatinine level	Urine output
Stage 1/risk	1.5-1.9 fold increase or ≥0.3 mg/dL increase	< mL/kg/hour during the 6-hours block
Stage 2/damage	>2-2.9 fold increase	< mL/kg/hour over two 6-hours blocks
Stage 3/failure	≥3 fold increase or >4 mg/dL	< mL/kg/hour for more than 24 hours or anuria for ≥12 hours

1. Acute Renal Failure

The treatment of ARF includes treatment of the underlying disease, prevention of rhabdomyolysis, fluid resuscitation, and renal replacement therapies. RIFLE and 2012 KDIGO (Kidney Disease: Improving Global Outcomes) criteria evaluated with serum creatinine (glomerular filtration rate) levels and urine output can be used in the diagnosis (19). It is recommended to start fluid resuscitation before the victims arrive at the hospital because fluid resuscitation provides adequate renal perfusion by increasing renal tubule flow and diluting nephrotoxins such as myoglobin. However, the best type of crystalloid to administer to patients remains controversial. Potassium-containing fluids are not particularly recommended. Because CS causes hyperkalemia, there is a concern that potassium in the fluid to be administered may worsen this condition. Lactated Ringer's solution and saline (0.45% or 0.9%) administered as crystalloids have not been found to be superior to one another. Because lactated Ringer's solution contains relatively high potassium, it is theoretically not recommended in CS with hyperkalemia. On the other hand, prolonged isotonic saline infusion may cause metabolic acidosis (16,18,20,21). In addition, clinical studies investigating the use of bicarbonate and/or diuretics to prevent the development of ARF or the role of mannitol in rhabdomyolysis are limited, with data lacking to reach a definitive recommendation. A recent comprehensive review emphasized that aggressive early-volume resuscitation with normal saline is currently recommended as the primary focus of treatment (18,22). Supporting data on the use of loop diuretics are limited to case reports (18). A central venous catheter should be inserted to appropriately administer fluid resuscitation to patients. Patient monitoring is also important. In addition, urine output is an important indicator in patients receiving fluid resuscitation. In cases where there is no urine output, the amount of fluid can be reduced to prevent volume overload. According to the KDIGO classification of ARF, conservative treatment is recommended in patients with stage 1 renal damage, conservative approach and renal replacement therapies should be considered in patients with stage 2 renal damage, and renal replacement therapies should be initiated in patients with stage 3 renal damage. Urgent dialysis indication should be considered in cases of uncorrectable metabolic acidosis, hyperkalemia that does not improve with treatment, other electrolyte disorders, the presence of uremia symptoms, presence of hypervolemia with oliguria or anuria (Table 2) (16). Compartment syndrome and peripheral neuropathy are seen as mechanical complications of CS.

2. a. Compartment Syndrome

Massive transfer of sodium and calcium into damaged cells promotes ischemia, leading to local edema and an increase in intracompartmental pressure. With an increase in intracompartmental pressure, muscle tissue undergoes necrosis. The diagnosis of compartment syndrome is primarily clinical. The most reliable finding is pain. The presence of a pulse does not rule out the diagnosis. Medical fasciotomy with mannitol treatment for decompression may be performed, preventing or prolonging the need for a surgical fasciotomy. Surgical fasciotomy reduces intracompartmental pressure by making surgical incisions to the fascia of the injured muscle. Routine application of early fasciotomy may reduce the necrotic muscle mass, severity of renal failure, risk of ischemic contracture, and peripheral neuropathy, but increases the risk of infection. Compartment syndrome is a major risk factor for sepsis (16,22).

b. Peripheral Neuropathy

Because of edema of the affected muscle, peripheral nerves are compressed, which may cause ischemia of nerve tissues, leading to paralysis and paresthesia. Proximal nerves are frequently affected. Symptoms regress in a few days or weeks in most cases but may be permanent (16).

3. Metabolic Irregularities

Typical metabolic changes in rhabdomyolysis include hyperkalemia, metabolic acidosis, hypocalcemia or hypercalcemia, hyperuricemia, hyponatremia, and hyperphosphatemia with possible cardiac dysrhythmias (23). The most common and most important laboratory disorder in rhabdomyolysis is hyperkalemia, which can cause cardiac arrhythmias and heart failure. Hyperkalemia occurs in the early period of the disease, and close follow-up is required. Potassium levels should be checked serially and strictly. Cardiac monitoring with electrocardiogram is necessary in patients with high potassium levels (>6 mmol/L). Electrocardiogram changes that accompany severe hyperkalemia (Widening QRS, small p waves, and severe arrhythmias) should be evaluated.

Early treatment should be administered with insulin-glucose infusion and inhaled beta-2 adrenergic agents. If hyperkalemia is resistant to these treatments, it should be treated with cation exchange resins (kayexalate) or dialysis. Calcium gluconate or calcium chloride should be used to treat hyperkalemia in patients with serum levels of 7 mmol/L or in the presence of life-threatening dysrhythmias. Hypocalcemia occurs early in rhabdomyolysis because of the entry of calcium into damaged cells and the accumulation of calcium phosphate in necrotic muscle. Because hypoalbuminemia is common in these patients, corrected calcium levels should be calculated. Treatment of early hypocalcemia should be avoided unless patients are symptomatic or have severe hyperkalemia. Correction of hypocalcemia with calcium chloride or gluconate should be avoided because calcium deposition may occur in the injured muscle. In the recovery phase, serum calcium levels may return to normal, causing hypercalcemia due to calcium release from the injured muscle and secondary hyperparathyroidism due to ARF. Similar to hyperkalemia, hyperphosphatemia occurs as a result of phosphate release from damaged muscle cells. It can cause further problems when phosphate binds to calcium and accumulates in soft tissues (16,18,20).

4. Disseminated Intravascular Coagulation

Disseminated intravascular coagulation (DIC) syndrome is a syndrome characterized by systemic activation of intravascular coagulation, resulting in fibrin formation in the circulation and thrombus formation in small and medium-sized vessels. DIC is observed in the acute stages of trauma. Thrombotic plugs in the vessels may cause organ dysfunction and hemorrhagic complications with continuous depletion of platelets and clotting factors. The secretion of thromboplastin from the traumatized muscle is a probable cause of this complication. Sepsis is another stimulant in the development of DIC (5,16,24).

5. Infections

In CS, infections emerge in the late period and are a significant cause of late mortality. Patients with CS are prone to all kinds of infections. Infections may develop due to the presence of open and dirty wounds due to trauma in the early periods, immunosuppression developing because of rhabdomyolysis, surgical interventions performed under non-sterile conditions, prolonged ICU stay, or insufficient healthcare workforce. It is necessary to urgently clean the wounds of these patients, remove dead tissues, administer culture-guided antibiotherapy after the initial empirical treatment, and ensure that the selected antibiotics are not nephrotoxic. In addition, a tetanus toxoid booster dose should be administered to every patient (10,25).

6. Other Medical Issues

During the initial stages of trauma, the symptoms of pain may not be evident. However, narcotic analgesics and ketamine may be used for pain observed in patients in later stages and during ICU follow-up. The use of non-steroidal anti-inflammatory drugs is not recommended in this setting (10,26). Pulmonary complications are common after CS, especially with the effect of trauma. These may include infective (pneumonia, empyema) or non-infective conditions such as obstruction in the respiratory tract or hemopneumothorax. Acute respiratory distress syndrome (ARDS) is an important entity that increases mortality. ARDS may also develop due to sepsis. The most important gastrointestinal problems are peptic ulcer formation and subsequent bleeding, in which case ARF may worsen.

Patients who lose their relatives, homes, families, and sometimes their limbs develop very severe traumas because of the earthquake. Evaluations by different disciplines are necessary to solve the physical problems in these patients, as well as regular psychiatric evaluation and support for such patients who may have psychological traumas (10,26,27).

Conclusion

In conclusion, earthquakes are an important fact of our geography. To prevent earthquake-induced CS and related mechanical complications, (such as compartment syndrome, peripheral neuropathy), AKI, DIC, and other unwanted events, it is necessary to start treatment at the scene of trauma and then continue the treatment in the ICU. It is important that the patients treated and followed in the ICU who are closely monitored should have been assessed with a multidisciplinary evaluation that also addresses cognitive and psychological aspects. With these considerations, we can reduce morbidity and mortality.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.Y.A., Y.Y., Concept: A.Y.A., Y.Y., Design: A.Y.A., Y.Y., Data Collection or Processing: A.Y.A., Y.Y., Analysis or Interpretation: A.Y.A., Y.Y., Literature Search: A.Y.A., Y.Y., Writing: A.Y.A., Y.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Aygin D, Atasoy I. Crush sendromu tedavi ve bakımı. Atatürk Üniversitesi Hemşirelik Yüksekokulu Dergisi 2008;11:93-100.
2. Hossain T, Ghazipura M, Dichter JR. Intensive Care Role in Disaster Management Critical Care Clinics. Crit Care Clin 2019;35:535-550.
3. Adhikari B, Mishra SR, Babu Marahatta S, et al. Earthquakes, fuelcrisis, power outages, and health care in Nepal: implications for the future. Disaster Med Public Health Prep 2017;11:625-632.
4. Nates JL, Nunnally M, Kleinpell R, et al. ICU admission, discharge, and triage guidelines: a frame work to enhance clinical operations, development of institutional policies, and further research. Crit Care Med 2016;44:1553-1602.
5. Turgut N, Adaş G, Akçakaya A, Mıngır T, Topuz C, Ay A. Deprem; Travma, Ezilme (Crush) Sendromu ve Kardiyopulmoner Resüsitasyon. Eur Arc Med Res 2012;28(Suppl 2):135-147.
6. Liu S, He C. Related Factors Associated With Earthquake Inpatient Mortality. Disaster Med Public Health Prep 2022;16:65-70.
7. Demirkiran O, Dikmen Y, Utku T, Urkmez S. Crush syndrome patients after the Marmara earthquake. Emerg Med J 2003;20:247-250.
8. Erek E, Sever MS, Serdengeçti K, et al. An overview of morbidity and mortality in patients with acute renal failure due to crush syndrome: the Marmara earthquake experience. Nephrol Dial Transplant 2002;17:33-40.
9. Gök M, Melik MA, Doğan B, Durukan P. Hospital crisis management after a disaster: from the epicenter of 2023 Türkiye-Syria earthquake. Ulus Travma Acil Cerrahi Derg 2023;29:792-797.
10. Kurultak İ. Crush syndrome in earthquake injured adult patients. TOTBİD Dergisi 2022;21:294-303.
11. Gonzalez D. Crush syndrome. Crit Care Med 2005;33(Suppl 1):34-41.
12. Oda J, Tanaka H, Yoshioka T, et al. Analysis of 372 Patients with Crush Syndrome Caused by the Hanshin-Awaji Earthquake. J Trauma 1997;42:470-476.
13. McMillan TE, Gardner WT, Schmidt AH, Johnstone AJ. Diagnosing acute compartment syndrome-where have we got to? Int Orthop 2019;43:2429-2435.
14. Huerta-Alardín AL, Varon J, Marik PE. Bench-to-bed side review: Rhabdomyolysis-an overview for clinicians. Crit Care 2004;9:158-169.
15. Yokota J. Crush Syndrome in Disaster. JMAJ 2005;48:341-352.
16. Koçer M, Karakısa H, Avcı A, Satar S. Rhabdomyolsis. Archives Medical Review Journal 2016;25:586-607.
17. Vanholder R, Sükrü Sever M, Lameire N. Kidney problems in disaster situations. Nephrol Ther 2021;17:27-36.
18. Kodadek L, Carmichael Ii SP, Seshadri A, et al. Rhabdomyolysis: an American association for the surgery of trauma critical care committee clinical consensus document. Trauma Surg Acute Care Open 2022;7:e000836.
19. Zhou J, Liu Y, Tang Y, et al. A comparison of RIFLE, AKIN, KDIGO, and Cys-C criteria for the definition of acute kidney injury in critically ill patients. Int Urol Nephrol 2016;48: 125-132.
20. Batur A. Traumatic Rhabdomyolysis (Crush Injury) Management. Anatolian Journal of Emergency Medicine 2023;6:41-46.
21. Scharman EJ, TroutmanWG. Prevention of kidney injury following rhabdomyolysis: a systematic review. Ann Pharmacother 2013;47:90-105.
22. Akdam H, Alp A. Crush Syndrome. Anatol J Med 2015;25:71-77.
23. Petejova N, Martinek A. Acute kidney injury due to rhabdomyolysis and renal replacement therapy: a critical review. Crit Care 2014;18:224.
24. Levi M. Disseminated intravascular coagulation. Crit Care Med 2007;35:2191-2195.
25. Ergönül Ö, Keske Ş, Ksinzik A, et al. The challenges in the monitoring of infectious diseases after the earthquake in Türkiye in 2023. Lancet Infect Dis 2023;23:482-488.
26. Sever MS, Vanholder R; RDRTF of ISN Work Group on Recommendations for the Management of Crush Victims in Mass Disasters. Recommendation for the management of crush victims in mass disasters. Nephrol Dial Transplan 2012;27(Suppl 1):1-67.
27. Shultz JM, Besser A, Kelly F, et al. Psychological consequences of indirect exposure to disaster due to the Haiti earthquake. Prehosp Disaster Med 2012;27:359-368.

DOI: 10.4274/csmedj.galenos.2023.2023-9-6

REVIEW

Cam and Sakura Med J 2023;3(Suppl 1):25-29

CSMJ

Pediatric Critical Care Approach for Children Exposed to Earthquakes

Nagehan Aslan[1], Dincer Yildizdas[2]

[1]Malatya Training and Research Hospital, Department of Pediatric Intensive Care, Malatya, Turkey
[2]Çukurova University Faculty of Medicine, Department of Pediatric Intensive Care, Adana, Turkey

ABSTRACT

Earthquakes are natural disasters that pose significant risks to children, who are particularly vulnerable to trauma and injuries. For a critical care approach to children exposed to earthquakes, rapid triage, and initial evaluation, proper management of Crush syndrome, electrolyte disorders, compartment syndrome, hypothermia, and infection control are important. In addition to these clinical management maneuvers, psychological support, family-centered care, staff training, and community preparedness are other significant issues in earthquakes. A well-prepared and coordinated approach is essential to meet the immediate and long-term medical and psychological needs of earthquake-affected children, thus increasing their chances of recovery and resilience. In this article, we discussed a critical care approach for pediatric patients exposed to earthquakes as a life-saving intervention.

Keywords: Earthquake, children, Crush syndrome, critical care approach

Introduction

Earthquakes are natural disasters that threaten human life and cause loss of life and property in a very short time. These natural disasters, which are common all over the world, can cause great destruction and loss of life (1). In Turkey, where a large part of the population faces the risk of earthquakes, destructive earthquakes are frequent. Most recently, more than 50 thousand lives were lost in the earthquakes centered in Kahramanmaraş on February 6, 2023, affecting 11 provinces and a population of approximately 13 million, and described by geoscientists as the most destructive terrestrial "double" earthquakes of the century (2).

Children are one of the most vulnerable groups during earthquakes. Children constitute a group that requires special attention in terms of trauma, injury, and emergency medical care needs caused by earthquakes (3). In this article, we provide important information about the approach to pediatric intensive care patients in earthquakes.

Evaluation of Children in the Earthquake

Earthquakes carry serious risks of building collapse, debris, injury, and trauma. During an earthquake, a large-scale mass fatality event, paradoxically, medical resources dwindle while the number of disaster victims presenting to hospitals for treatment

CAM & SAKURA MEDICAL JOURNAL

Address for Correspondence: Nagehan Aslan MD, Malatya Training and Research Hospital, Department of Pediatric Intensive Care, Malatya, Turkey
Phone: +90 505 549 99 86 **E-mail:** nagehan_aslan@hotmail.com **ORCID ID:** orcid.org/0000-0002-6140-8873
Received: 19.09.2023 **Accepted:** 27.10.2023

increases at the same rate. Critical care services must continue to function efficiently to provide care for many patients when injuries or illnesses affect the local population in disaster events. Intensive care units and emergency departments play a key role in disasters and mass casualty events (4). Children injured or severely traumatized by earthquakes may require intensive care units (5).

In mass disaster situations, critical care service function differently compared with their routine functioning. The purpose of critical care in a disaster situation is to establish a triage system to assess and prioritize the medical needs of children. By classifying patients according to different levels of severity, triage ensures immediate intervention for those in critical condition and saves as many lives as possible. Effective triage ensures that patients receive the care they need in the right place, at the right time, and with the right resources. This will prevent the misuse of critical care resources and labor for patients who would have survived without these resources (4,5).

Early and rapid identification of fatal earthquake-related trauma and provision of optimal care are crucial for reducing mortality in pediatric patients. The most common cause of death in earthquakes is penetrating and blunt trauma to vital organs (5,6). All patients extracted from the rubble should be considered to have multiple traumas and should be treated. In the first moments of the disaster, death frequently occurs due to organ injuries related to head, thorax, and abdominal trauma, while asphyxia, hypovolemia, and hypothermia are the leading causes of death in the following hours (3). Crush syndrome and related acute kidney injury (AKI) and compartment syndrome are at risk of developing in all patients who have been under debris for long hours and days, who are rescued alive from the rubble, but who have different levels of muscle trauma (7). Patients who develop compartment syndrome may require fasciotomy and amputation (8).

The initial evaluation of pediatric patients in the emergency department is critical in terms of the type and severity of injuries. The main objectives in the initial evaluation can be generalized as ensuring airway patency, stabilizing circulation, and treating existing injuries. Regarding treatment in the pediatric intensive care unit, the main objectives are maintaining airway patency, appropriate fluid replacement, bleeding control, providing appropriate analgesia, prevention, and management of hypothermia, and management of Crush syndrome and related renal and systemic complications (4,6,7).

Opening the Airway

The patient's airway should be opened by cervical stabilization and oxygen support should be provided. Advanced airway support should be provided when necessary (9).

Crush Syndrome

Crush syndrome is a medical emergency caused by prolonged pressure on an area of the body. This pressure can occur during events such as an accident, building collapse, or natural disaster. Compressed or crushed tissue in the body causes harmful substances to be released into the bloodstream. One of these harmful substances is myoglobin. Myoglobin is a protein found in muscle tissue that can leak into the blood when muscles are damaged or crushed. Other dangerous substances, such as potassium, can also be released from damaged muscle cells (7,10).

Crush syndrome occurs after rhabdomyolysis due to muscle trauma. The most practical method for the diagnosis of rhabdomyolysis is a serum creatine kinase level more than 5 times higher than the laboratory normal. In rhabdomyolysis, substances such as lactic acid, thromboplastin, creatinine kinase, nucleic acids, phosphate, creatinine, myoglobin, and potassium in the striated muscle cells (myocytes) pass into the bloodstream; substances such as calcium, water, and sodium enter the muscle cells (10). These events predispose patients to Crush syndrome and AKI, which is one of the most important elements of this picture (7,11).

Clinical findings in patients with Crush syndrome are analyzed under the headings of local symptoms in the crushed muscles and systemic findings related to the substances released from these muscles (Crush syndrome findings) (10). A typical local finding in patients is compartment syndrome (8). Systemic findings vary greatly depending on the organ and system primarily affected by the condition. The most common findings are hypotension/shock, cardiac and respiratory failure, and AKI. Therefore, timely and appropriate management is vital to prevent these complications (12).

Crush syndrome is a clinical entity that affects not only muscle destruction and multiple organs and systems. It may present with AKI, hypovolemic shock, electrolyte disturbances, sepsis, and disseminated intravascular coagulation. The primary treatment approach is fluid resuscitation as early as possible to correct hypovolemia. Hydration increases renal perfusion and prevents obstruction in the tubules. The most important step for treating Crush syndrome is fluid therapy (12,13).

If possible, starting fluid therapy from the first extremity that can be reached while the patient is still under the rubble will reduce mortality and morbidity. Isotonic NaCl is recommended for fluid therapy because it is the most readily available fluid (12). Isotonic NaCl should be administered at an infusion rate of 15-20 mL/kg/h in children. In patients who stay under debris for a long time, a hypotonic NaCl + bicarbonate mixture may be preferred if it can be found. This solution was prepared by mixing 50 mEq/L bicarbonate into 0.45% NaCl +5% dextrose (1/2 SF) solution to prepare an alkalized solution. The rationale for administering bicarbonate solution for fluid resuscitation is to raise the urine pH above 6.5 to prevent Tamm-Horsfall protein and heme protein precipitation, intratubular plug formation, and uric acid precipitation. This will reduce metabolic acidosis and hyperkalemia; however, bicarbonate supply may be difficult in disasters with mass impact. In such cases, the preferred fluid is an isotonic sodium chloride solution. The infusion rate of fluid therapy should be decreased and adjusted to 10 mL/kg/h as the time to extract the patient from the debris increases. In patients in whom intravenous access cannot be established, intraosseous access should be open and fluid therapy should be started in the early period (14,15,16).

In patients with Crush syndrome who reach the hospital, maintenance fluid therapy can be continued on 3000 cc/m^2/day if there is urine output. Patients undergoing fluid replacement should be closely monitored for complications such as signs of overload and metabolic acidosis. However, if the patient is anuric, classical AKI treatment principles should be followed. Daily fluid therapy should be calculated as 400 cc/m^2+ insensible loss, and the patient should be closely monitored for dialysis indications (16,17).

Dialysis has an important place in treatment. Intermittent hemodialysis, continuous renal replacement therapy, and peritoneal dialysis can be used; however, intermittent hemodialysis is the most effective and will be preferred in the aftermath of an earthquake when medical and logistical considerations are considered (18,19,20). Timely and appropriate treatment of Crush syndrome can increase patients' chances of survival and improve long-term health outcomes.

Electrolyte Imbalances

In particular, hyperpotassemia stands out as the most important laboratory finding in patients with Crush syndrome recovered from the rubble. Because earthquake conditions are such that elective diagnostic approach cannot be performed, the treatment plan should be organized empirically. According to the assumptions, many survivors of earthquakes die from hyperpotassemia. Performing laboratory tests or waiting for the results for initiation of treatment may cause acute loss of the patient who is extracted alive from the rubble due to electrolyte imbalance. Therefore, care should be taken to ensure that potassium is not present in the fluid to be administered and that potassium-containing fluids such as Ringer lactate are not given. Hyperphosphatemia, hypocalcemia, and hypoalbuminemia are also frequently observed in these patients (19,21).

Compartment Syndrome

This is the name given to the increase in the normally very low (0-15 mmHg) pressure of the closed spaces (compartments) surrounded by rigid fascia in which the muscles are located (22). Clinical findings and intra-compartmental pressure measurements are useful in the diagnosis of compartment syndrome. The simplest and most effective treatment for this syndrome is surgical opening of the fascia (or fasciotomy). Prophylactic fasciotomy is not recommended in all patients with Crush syndrome to prevent the development of compartment syndrome. Fasciotomy is particularly indicated if there are progressive clinical signs of acute compartment syndrome associated with the absence of mediastinal pulses or confirmed elevation of compartment pressures (8,23).

Amputation is recommended when a limb is unsalvageable and the injury causes sepsis, systemic inflammation, or uncontrollable bleeding. Patients who develop compartment syndrome and require amputation should be closely followed by the orthopedics and traumatology and physical therapy and rehabilitation branches (24).

There is limited evidence that hyperbaric oxygen therapy may improve perfusion, accelerate wound healing, and reduce surgical interventions by reducing oxidative stress and inflammation in patients with compartment syndrome (25).

Hypothermia

Hypothermia is defined as an involuntary decrease in the central body temperature below 35 °C. Patients with multiple and central nervous system trauma are prone to hypothermia. Hypothermia causes severe coagulopathy, complicates bleeding control, increases the need for transfusion, and is associated with serious mortality and morbidity. Appropriate central temperature measurements are required for the diagnosis of hypothermia. Treatment of systemic hypothermia and maintenance of local frostbite with general supportive therapies and rewarming applications are required (26).

Infection Control

It is critical to maintain strict infection control protocols to prevent the spread of diseases, especially in pediatric intensive care units. Adequate sanitation, hand hygiene, and isolation of infectious patients are essential measures for infection control. However, after an earthquake, it becomes difficult to maintain proper infection control measures because of limited resources and overcrowded conditions. In particular, wound infections are common. Therefore, wound care and debridement of contaminated wounds are essential for infection control. Antibiotherapy administered without source control not only is not therapeutic but also creates problems in terms of antibiotic resistance and the growth of resistant microorganisms. If the patient has signs of systemic infection, culture samples should be taken, and antibiotherapy with the appropriate spectrum should be started (27).

Emotional Trauma

Earthquakes are emotionally traumatic for children and can cause anxiety, fear, and distress. It is necessary to create a pediatric intensive care environment in which children affected by earthquakes feel safe. Both children and their families may need psychosocial support to cope with the serious psychological effects and stress of the earthquake. Therefore, it is essential that psychologists and psychiatrists participate in the treatment team (28,29).

Family-centered Patient Care and Communication with the Family

Families of patients hospitalized in pediatric intensive care for earthquake or other reasons are under great stress. There may be deaths or missing family members due to the earthquake. The extent of the impact on the family is directly reflected in the patient being treated in pediatric intensive care. The pediatric intensive care team should establish effective communication with families, provide up-to-date information about the child's health status, and, if possible, involve the family in the treatment process (30).

Training

Pediatric intensive care and hospital staff should be trained in disaster medicine at regular intervals. If necessary, drills and simulations should be conducted to ensure that the team is prepared for any disaster situation (31).

Coordination

Effective communication and coordination among healthcare providers, government agencies, and non-governmental organizations in a hospital under disaster conditions is a key component of a successful pediatric intensive care approach. Establishing continuous lines of communication and collaboration ensures the efficient use of available medical resources and rapid provision of depleted resources. Communication will also ensure that children who cannot receive the treatment they need under the current disaster conditions can access the care they need through an effective referral chain (32).

Conclusion

In conclusion, earthquakes are natural disasters that can have devastating consequences for children. It is essential to prioritize the health of pediatric patients, our most vulnerable patient group, in times of crisis. The timing of major disasters such as earthquakes is unpredictable, but it is necessary to be prepared in every aspect to minimize the devastating effects. Crush syndrome is a clinical picture that all physicians should be aware of, and early and appropriate intervention can life-save. A well-prepared pediatric intensive care approach is essential to meet the immediate and long-term medical and psychological needs to survive children. Rapid intervention in pediatric intensive care patients with a trained and coordinated healthcare team, access to effective treatment methods requiring advanced equipment, infection control, family-centered care, and psychosocial support will significantly increase the chances of recovery and resilience of children exposed to earthquakes. The most important step to prevent children from being exposed to earthquake trauma is to increase earthquake preparedness in the community and take the necessary measures to ensure that children remain safe.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: N.A, Concept: N.A, Design: N.A, Data Collection or Processing: N.A, Analysis or Interpretation: N.A, Literature Search: N.A, D.Y., Writing: N.A, D.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Peleg K, Reuveni H, Stein M. Earthquake disasters--lessons to be learned. Isr Med Assoc J 2002;4:361-365.
2. Ni S, Sun H, Somerville P, et al. Complexities of the Turkey-Syria doublet earthquake sequence. Innovation (Camb) 2023;4:100431.
3. Jacquet GA, Hansoti B, Vu A, Bayram JD. Earthquake-related injuries in the pediatric population: a systematic review. PLoS Curr 2013;5:ecurrents.dis.6d3efba2712560727c0a551f4febac16.
4. Wax RS. Preparing the intensive care unit for disaster. Crit Care Clin 2019;35:551-562.
5. Desmond M, Schwengel D, Chilson K, et al. Paediatric patients in mass casualty incidents: a comprehensive review and call to action. Br J Anaesth 2022;128:109-119.
6. Doocy S, Daniels A, Packer C, Dick A, Kirsch TD. The human impact of earthquakes: a historical review of events 1980-2009 and systematic literature review. PLoS Curr 2013:5.
7. Ramírez-Guerrero G, Reis T, Marcello M, de Cal M, Ronco C. Crush syndrome-related acute kidney injury in earthquake victims, time to consider new therapeutical options? Int J Artif Organs 2023:3913988231191954.
8. Reis ND, Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome: with special reference to earthquake casualties. J Bone Joint Surg Br 2005;87:450-453.
9. Wang W, Zhang X, Sang W, et al. Trauma assessment and first aid in the confined spaces after major natural disasters. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue 2023;35:777-781.
10. Reingardienė D, Jodžiūnienė L, Lažauskas R. Raumenų sutraiškymas ir sutraiškymo sindromas [Muscle crush injury and Crush syndrome]. Medicina (Kaunas) 2010;46:435-441.
11. He Q, Wang F, Li G, et al. Crush syndrome and acute kidney injury in the Wenchuan Earthquake. J Trauma 2011;70:1213-1217.
12. Shimazu T, Yoshioka T, Nakata Y, et al. Fluid resuscitation and systemic complications in Crush syndrome: 14 Hanshin-Awaji earthquake patients. J Trauma 1997;42:641-646.
13. Dönmez O, Meral A, Yavuz M, Durmaz O. Crush syndrome of children in the Marmara earthquake, Turkey. Pediatr Int 2001;43:678-682.
14. Sanadgol H, Najafi I, Rajabi Vahid M, Hosseini M, Ghafari A. Fluid therapy in pediatric victims of the 2003 Bam, Iran earthquake. Prehosp Disaster Med 2009;24:448-452.
15. Iraj N, Saeed S, Mostafa H, et al. Prophylactic fluid therapy in crushed victims of Bam earthquake. Am J Emerg Med 2011;29:738-742.
16. Sagheb MM, Sharifian M, Roozbeh J, Moini M, Gholami K, Sadeghi H. Effect of fluid therapy on prevention of acute renal failure in Bam earthquake crush victims. Ren Fail 2008;30:831-835.
17. Sever MS, Sever L, Vanholder R. Disasters, children and the kidneys. Pediatr Nephrol 2020;35:1381-1393.
18. Bonomini M, Stuard S, Dal Canton A. Dialysis practice and patient outcome in the aftermath of the earthquake at L'Aquila, Italy, April 2009. Nephrol Dial Transplant 2011;26:2595-2603.
19. Scapellato S, Maria S, Castorina G, Sciuto G. Sindrome da schiacciamento [Crush syndrome]. Minerva Chir 2007;62:285-292.
20. Li N, Wang X, Wang P, Fan H, Hou S, Gong Y. Emerging medical therapies in Crush syndrome-progress report from basic sciences and potential future avenues. Ren Fail 2020;42:656-666.
21. Sever MS, Erek E, Vanholder R, et al. Serum potassium in the Crush syndrome victims of the Marmara disaster. Clin Nephrol 2003;59:326-333.
22. Hansen EL, Pedersen L, Lindberg-Larsen M. Acute compartment syndrome. Ugeskr Laeger 2021;183:V11200817.
23. Better OS, Rubinstein I, Reis DN. Muscle crush compartment syndrome: fulminant local edema with threatening systemic effects. Kidney Int 2003;63:1155-1157.
24. Zhang D, Janssen SJ, Tarabochia M, von Keudell A, Chen N. Risk factors for death and amputation in acute leg compartment syndrome. Eur J Orthop Surg Traumatol 2020;30:359-365.
25. Karam MD, Amendola A, Mendoza-Lattes S. Case report: successful treatment of acute exertional paraspinal compartment syndrome with hyperbaric oxygen therapy. Iowa Orthop J 2010;30:188-190.
26. Strapazzon G, Avancini G, Blancher M. Accidental hypothermia. N Engl J Med 2013;368:681-682.
27. Hines EM, Dowling S, Hegerty F, Pelecanos A, Tetsworth K. Bacterial infection of fasciotomy wounds following decompression for acute compartment syndrome. Injury 2021;52:2914-2919.
28. Cui YH. Psychological trauma and crisis intervention in children after earthquake. Zhongguo Dang Dai Er Ke Za Zhi 2013;15:423-426.
29. Xu J, Xie L, Li B, Li N, Yang Y. Anxiety symptoms among children after the Wenchuan earthquake in China. Nord J Psychiatry 2012;66:349-354.
30. Lin CH, Sun YJ, Tzeng WC, Chiang LC. Family-centered care and post-traumatic stress disorder. Hu Li Za Zhi 2012;59:5-10.
31. Ingrassia PL, Pigozzi L, Bono M, Ragazzoni L, Della Corte F. Use of simulated patients in disaster medicine training: a systematic review. Disaster Med Public Health Prep 2021;15:99-104.
32. Korkut S, Altinarik S, Türk O, et al. Importance of team experience and coordination in disaster response: building collapse. Disaster Med Public Health Prep 2022;16:1341-1345.

DOI: 10.4274/csmedj.galenos.2023.2023-9-4
Cam and Sakura Med J 2023;3(Suppl 1):30-41
CSMJ

Hyperbaric Oxygen Therapy for Earthquake Victims

Kübra Özgök Kangal[1], Abdullah Arslan[2]

[1]University of Health Sciences Turkey, Gülhane Training and Research Hospital, Department of Underwater and Hyperbaric Medicine, Ankara, Turkey
[2]Necmettin Erbakan University, Meram Faculty of Medicine, Department of Underwater and Hyperbaric Medicine, Konya, Turkey

ABSTRACT

Earthquakes are catastrophic natural disasters. Staying under rubble for a long time may cause compartment syndrome, especially in the extremities, and crush injuries due to severe trauma. In addition, frostbite injuries may occur due to extreme climate in the winter. In hyperbaric oxygen therapy (HBOT), patients breathe 100% oxygen in a closed chamber at pressures greater than 1 atmosphere absolute. HBOT provides elevated partial oxygen pressure, increased oxygen diffusion distance, decreased edema of the areas with circulatory disorder, augmented bactericidal effect, additive-synergistic effect with antibiotics, and enhanced wound healing. HBOT is a successful adjunctive treatment option for crush injuries, acute skeletal compartment syndromes, and frostbite injuries.

Keywords: Hyperbaric oxygen therapy, earthquakes, compartment syndrome, crush injuries, frostbite

Introduction

Earthquakes are catastrophic natural disasters. Severe earthquakes cause many deaths and serious traumatic injuries. Each year, approximately one million earthquakes occur, which indicates that every 2 minutes, an earthquake occurs (1). Earthquakes are an immutable fact of Turkey, and many devastating earthquakes have occurred throughout the history of Turkey. The latest earthquake disaster on February 6th, 2023, destroyed many buildings, resulting in thousands of deaths and severe injuries due to demolitions. There was an inevitable overload of healthcare services in the earthquake region due to damaged hospitals, injured medical personnel, ongoing search and rescue operations, and thousands of emergency applications to hospitals. Earthquake victims were distributed throughout Turkey quickly, and multidisciplinary treatment was provided to the patients.

Many physical injuries, such as being trapped under rubble, being stuck between objects, burns, and frostbites, are reported in earthquakes (2). Staying under rubble for a long time may cause compartment syndrome, especially in the extremities, and crush injuries due to severe trauma. Victims may have multiple or isolated injuries. Patients should be treated multidisciplinary (1). Hyperbaric oxygen therapy (HBOT) has been used in traumas, particularly crush injuries and compartment syndrome.

Address for Correspondence: Assoc. Prof. Kübra Özgök Kangal, University of Health Sciences Turkey, Gülhane Training and Research Hospital, Department of Underwater and Hyperbaric Medicine, Ankara, Turkey
Phone: +90 543 781 14 24 **E-mail:** kubra_ozgk@hotmail.com **ORCID ID:** orcid.org/0000-0002-2449-4821
Received: 18.09.2023 **Accepted:** 22.11.2023

CAM & SAKURA MEDICAL JOURNAL

Hyperbaric Oxygen Therapy

HBOT is a treatment modality in which patients breathe 100% oxygen in a closed chamber at pressures higher than 1 atmosphere absolute (ATA) (3). Monoplace and multiplace pressure chambers are used for HBOT. After reaching the desired treatment pressure, patients begin to breathe 100% oxygen through a mask, hood, or endotracheal intubation tube.

Increased ambient pressure and increased partial oxygen pressure are the two fundamental mechanisms of HBOT. Increased ambient pressure eliminates gas bubbles formed in the body due to decompression sickness, gas gangrene, or gas embolism. However, the main HBOT effects are related to the increased partial pressure of oxygen. An increase in oxygen diffusion distance, decrease in edema in the areas with circulatory disorder, increase in bactericidal effect, and additive-synergistic effect with antibiotics are the effects that occur due to the increase in partial oxygen pressure (3,4). In severe crush injuries, HBOT is accepted as an adjunctive treatment for saving the extremity or preventing amputation (4). The following sections will discuss the effects of HBOT in cases such as crush injuries, compartment syndrome, burns, and frostbite seen in earthquakes.

1. Crush Injuries

The most common earthquake-related injuries are musculoskeletal trauma (65%), fractures (22%), and soft tissue contusions or sprains (6%). Open fractures were reported to be between 11% and 54%. While 36% of patients with bone fractures have multiple fractures, 6% have accompanying neurovascular damage (1).

Crush injuries occur due to high-energy impact, especially on the extremities and trunk. It varies from skin tissue trauma to bone, muscle, and tendon injuries. Trauma is caused by high-pressure force (4). In massive earthquakes, crush injuries occur in 3-20% of the population (1). Direct tissue damage due to impact and subsequent ischemic tissue damage occurs. Direct tissue damage may result in tissue edema, muscle necrosis, and nerve damage in the damaged area.

For an injury to qualify as a crush injury, the following criteria must be met:

(i) Two or more tissues (e.g., muscle, bone, skin, ligament, nerve) must be involved.

(ii) The injury must be severe enough to question tissue survival.

(iii) There is a gray area between irreversibly damaged and minimally traumatized tissues. Increasing the survival of gray zone tissue is the most crucial aspect of crush injury treatment (5).

The treatment of crush injury involves two steps. First, it is necessary to immediately manage traumatic necrotic tissues. These include orthopedic and vascular surgical procedures such as debridement, repair of injured vessels, stabilization of broken bones, and soft tissue repair. At the same time, tissue perfusion must be ensured. Anticoagulants, fluid replacement, blood transfusion, and agents that support tissue perfusion should be used. Antibiotic use and dressings are significant in open wounds (5). During periods of muscle breakdown, patients may develop acute renal failure (6).

Smith et al. (7) reported the promising effects of HBOT in addition to surgical treatment in crush injuries. Székely et al. (8) applied HBOT to 19 patients with serious injuries to the arms and legs, vascular damage, severe skin loss, and anaerobic infection due to open fractures. The authors stated that they treated extremities that would require amputation according to their experience. They also emphasized that HBOT enhanced skin graft healing in necessary patients. An average of 10 sessions of HBOT were administered to each patient, and promising therapeutic outcomes were documented in 13 cases (68%) (8). Monies-Chass et al. (9) presented a case series of 7 patients with severe vascular trauma in the extremities. Although standard vascular repair was successful in this study, HBOT was applied to patients with critical ischemia in the extremities after surgery. The authors reported that gangrene development was prevented in all cases, complete recovery was achieved in 6 patients, and toe amputation was required in only one patient (9).

A few randomized studies have analyzed the efficacy of HBOT in crush injuries. One study by Bouachour et al. (10) included 36 patients with crush injuries. Patients were randomly divided into two groups within the first 24 hours after surgery. The first group was treated with HBOT at 2.5 ATA for 90 minutes twice daily for six days. The placebo group received treatment with 21% oxygen at 1.1 ATA for 90 minutes twice daily for six days. All patients were administered the same standard treatments (anticoagulants, antibiotics, wound dressings). Complete recovery was achieved in 17 patients in the HBOT group and 10 patients in the placebo group ($p<0.01$). One patient in the HBOT group and six patients in the placebo group underwent new surgical procedures (skin flaps and grafts, vascular surgery, and amputation) ($p<0.05$). This study demonstrates the promising outcomes of HBOT in improving wound healing and reducing the number of repetitive surgeries. HBOT is a beneficial adjunctive therapy for treating severe (stage III) crush injuries in the extremities in patients over 40 years of age (10). In another randomized controlled trial, patients with open tibia fractures were randomized to receive 12 sessions of HBOT in addition to standard trauma care or standard care within the first 48 hours of injury. One hundred and twenty patients were included. In the HBOT group, necrosis and infection were significantly less in the postoperative four days ($p<0.05$). Patients who received HBOT had fewer late complications, including delayed fracture. In the first and second years, quality of life measures were superior in HBOT patients (11).

The Marmara earthquake occurred on August 17th, 1999, and was one of the most destructive earthquakes in our country's history. In a related study, 52 earthquake victims with fasciotomy due to compartment syndrome received HBOT. Forty-five patients had crush injuries. Only five patients progressed to amputation, whereas the extremities were preserved in other patients. HBOT was applied at 2.5 ATA for 3 to 70 sessions (12). In another study, the authors reviewed the outcomes of seven patients with lower extremity trauma. HBOT has many benefits regarding wound healing in lower extremity traumas, returning to daily activities, and preventing complications (13).

Hyperbaric Oxygen Indication for Crush Injuries

The Underwater and Hyperbaric Medical Society (UHMS) recommends using standard classification systems for crush injuries. Currently, the Gustilo Grading System is frequently used. According to UHMS, the HBOT recommendations begin with grade I for decompensated hosts, grade III-A for impaired hosts, and grade III-B for healthy persons. The details are explained in Tables 1, 2.

HBOT should be applied once in the first 24 hours, at pressures of 2.2-2.8 ATA, and twice daily for the next three days. Transferring patients for HBOT in the first 24 hours can be challenging. Post-anesthesia recovery after significant surgeries, transferring them to HBOT units, and stabilizing in the pressure chamber require experienced teamwork. It may be necessary to continue HBOT after the first 4 days because of infection, delayed wound healing, and ischemic complications at the operation site (14).

HBOT should be applied as soon as possible. When reperfusion starts again, reperfusion damage begins in the first 4-6 h and damages the microcirculation. In addition to the circulatory disorder at the time of the initial trauma, reperfusion injury should not be ignored. Therefore, it is crucial to start HBOT from the first day of reperfusion injury (14).

2. Acute Skeletal Muscle Compartment Syndrome

Acute skeletal muscle compartment syndrome (SCMS) is another significant challenge of earthquakes. It occurs when the increased pressure within a compartment disturbs the circulation and function of tissues within the same space (15). When a limb is stuck under rubble, the pressure of the compartments in the trapped limb increases both by external mechanical pressing stress and secondary cellular events such as worsening tissue edema related to fluid extravasation. The injured limb might not be painful, swollen, or tense immediately after the extrication of the earthquake victim. The limb is often numb with a peripheral pulse. It will quickly become tense and swollen within the following hours. The crushed limb can be bruised and discolored with intact skin. Pain will develop gradually. The intracompartmental pressure can be measured. The classical management of acute SCMS includes immediate fasciotomy to achieve decompression, thereby improving local and distal blood circulation. Turning a closed injury into an open wound carries clear risks, including profuse bleeding, aggravating coagulopathy, complicating

Table 1. Gustillo grading system and criteria for the use of adjuvant HBOT in crush injuries

Gustillo type	I	II	III (Crush injuries)		
			III-A	III-B	III-C
Findings (soft tissue injury with fractures)	Minimal (<1 cm wide) puncture wound from inside to outside	Laceration with minimal deep soft tissue damage	Sufficient soft tissue to close the wound (after debridment)	Flaps and/or grafts needed for bone coverage	III-B injuries with major vascular damage
HBOT indication					
Healthy host[1]	-	-	-	+	+
Impaired host[1]			+	+	+/-[2]
Decomposed host[1]	+	+	+	+/-[2]	+/-[2]

Adapted from UHMS Hyperbaric Oxygen Therapy Indications (14th ed, p. 139) by R.E. Moon, 2019. HBOT may help with the primary healing of amputation flaps. [1]Refer to the health status score table, [2]Consider primary amputation in decompensated hosts with grade III-B and III-C injuries. HBOT: Hyperbaric oxygen therapy, UHMS: Underwater and Hyperbaric Medical Society

Table 2. Health status score table

Assessment	2 Points	1 Points	0 Points
	Use half points if mixed or intermediate between 2 grades		
Activities of daily living	Full	Some	None
Ambulation	Community	Household	None
	Subtract $^{1}/_{2}$ point if aids are used		
Comorbidities	No significant	Impaired	Decompensated
	Omit neurological deficits, which is a separate assessment below		
Inhibitors Smoking, collagen vascular diseases, and immunosuppressors	None	Past	Current
Neurological deficits	None	Some/minor Sensation, imbalances	Major Cognitive, paralysis

Adapted from UHMS Hyperbaric Oxygen Therapy Indications (14th ed, p. 139) by R.E. Moon, 2019. Five assessments are each graded from 2 points (best) to 0 points (worst) and summated to generate a score of 0-10. Scores between $7^{1/2}$ and 10 points indicate "healthy host", scores between $3^{1/2}$ and 7 points indicate "impaired host", and scores between 0 and 3 points indicate "decompensated host". UHMS: Underwater and Hyperbaric Medical Society

dialysis for myoglobinuric acute renal failure, infections, and limb-threatening sepsis (16). Görmeli et al. (17) reported five (24%) cases of sepsis, seven (24%) of amputations, and seven (33%) of mortality after urgent fasciotomy among 21 patients who experienced the Van earthquake in 2011. In the study by Duman et al. (18), the amputation rate was 25% among 16 patients who underwent urgent fasciotomy after the Marmara earthquake in 1999. Due to the massive burden on hospitals, clinicians may decide to perform prophylactic fasciotomy because they usually do not have enough time to perform frequent physical examinations for patients with suspected/impending stage SMCS (19). However, this overwhelming demand on surgeons may lead to inadequate follow-ups after fasciotomies, resulting in post-fasciotomy complications. In this respect, HBOT may provide better outcomes in the early stages of SCMS by preventing surgical complications (3,20).

HBOT increases tissue fluid oxygenation 10-fold, reduces edema by 20%, increases oxygen diffusion distances 3-fold, and enhances wound healing. In this respect, HBOT might break the self-perpetuating vicious cycle of edema-ischemia. HBOT may prevent SCMS in its early stages, improve outcomes, and be used as adjunctive therapy for wound management and residual problems after fasciotomy (3,20).

In the study by Strauss et al. (21), dogs with induced SCMS were exposed to HBOT, and muscle damage was significantly reduced. The authors suggested that HBOT may be beneficial when immediate surgical decompression is unavailable, in the impending stage of SCMS with no surgical indication, and after surgical decompression (21). Another canine compartment syndrome study by Skyhar et al. (22) demonstrated that HBOT significantly reduced tissue edema and necrosis even in a hypotensive state. Strauss et al. (23) reported that 2 hours of delayed HBOT significantly reduced edema and muscle necrosis in a model compartment syndrome. In a study by Bartlett et al. (24), muscle function significantly improved in a canine SMCS with a combination of HBOT and fasciotomy versus the fasciotomy group alone. Aydin et al. (25) reported that combining HBOT and fasciotomy led to a more significant reduction in intracompartmental pressures than HBOT alone, fasciotomy alone, and control.

There is no existing randomized controlled trial about SMCS and HBOT. Currently, there are only case reports that are primarily non-traumatic, as listed in Table 3 (26,27,28,29,30,31,32). In contrast, Korambayil et al. (33) reviewed their compartment syndrome experiences due to snake bites. Among 112 snake bite cases, 24 patients presented with SCMS. HBOT sessions were administered after the initial treatment with anti-snake venom and antibiotics, and no fasciotomy was required. The authors concluded that HBOT is a successful treatment modality for managing "impending" compartment syndrome, which may require later fasciotomy (33).

The HBOT indication for SMSC is considered as class 1, level C according to The American Heart Association, with the benefits outweighing the risks, the treatments are helpful based on expert opinion (including laboratory data), and case studies support HBOT use, but no randomized controlled trial exists (20).

Table 3. Case reports on HBOT use for compartment syndrome

Authors	Number of patients	Diagnosis and etiology	Symptoms	Surgical interventions	HBOT	Final outcome
Lee et al. (26) 2020	1 patient	Compartment syndrome due to acute isocyanate inhalation (severe rabdomyolisis resulting in bilateral lower leg compartment syndrome)	Pain, stiffness, numbness, paralysis, and lower leg tissue pressure increased to 180 mmHg/170 mmHg (right/left)	Fasciotomy (all four compartments for both legs)	HBOT started the next day, 2.0 ATA, 90 mins, twice a day up to 7 seven days	No amputation. Walks with slight weakness and without major complications
Han et al. (27) 2018	1 patient	Compartment syndrome in unconscious acute carbon monoxide poisoning	Swelling, pulses +, normal capillary refill time, motor weakness, sensory impairment	Fasciotomy was performed with 12 h delay after diagnosis (the medial and the lateral sides of the left forearm)	HBOT started immediately because of carbon monoxide poisoning. 3 sessions	Left median, ulnar, radial, and musculocutaneous nerve pathology and neurological sequelae including wrist drop
Mendes et al. (28) 2018	1 patient	Bilateral upper extremity compartment syndrome after intense physical training	Swelling and pain	None	2.3-2.5 ATA 90 min, twice daily	Asymptomatic, able to perform intense physical trainings
Hoy et al. (30) 2018	1 patient	Severe supraspinatus muscle rhabdomyolysis following overexertion	Pain, right shoulder weakness	Fasciotomy (intraoperative notes; poorly contracting muscles)	Three HBOT sessions within 24 h post-fasciotomy, completing 7 HBOT sessions over a 5-day period.	One month later, the patient had a full active range of motion of the right shoulder in the absence of painful symptoms
Abdullah et al. (31) 2006	1 patient	Heroin-induced severe bilateral compartment syndrome	Severe pain, burning sensation, severe swelling, tenderness, weakness, and absent plantar reflexes	Fasciotomy (all four compartments for both legs)	2.4 ATA, 90 min, daily	Wounds were closed after 10 days and healed. There was mild improvement in the strength of the lower extremities
Al et al. (29) 2012	1 patient	Upper extremity compartment syndrome in an unconscious acute carbon monoxide poisoning case	Swelling, rash, weakened pulses, paresthesia, paralysis, pallor, and pain in the arm during passive movements	Fasciotomy (four compartments), pulses returned after fasciotomy	HBOT started immediately because of carbon monoxide poisoning. Total number of sessions unknown	A skin graft was administered 10 days after fasciotomy. The patient discharged without any motor or sensorineural symptoms
Fitzpatrick et al. (32) 1998	1 patients	Compartment syndrome associated with acute exertional injury	Pain to the anterior right lower leg, with good pulses and normal sensation to the right foot, 33 h of progressive ischemia	Fasciotomy (four compartment release). Intraoperative notes: muscle purple to deep red and slightly hemorrhagic; no muscle contractility during electrocautery	Referred for HBOT 6 days after surgery (due to minimal reduction in edema to the surgical site) 2.4 ATA, 90 min, daily, 7 sessions	Edema reduced, and no further surgery or grafts were required. The patient could resume his full military duties with restrictions on running

HBOT: Hyperbaric oxygen therapy, ATA: Atmosphere absolute, h: Hour, min: Minute

HBOT Indication for SCMS

The clinical presentation of SCMS may be divided into three stages, "suspected", "impending", and "established", in which the self-perpetuating edema-ischemia cycle is a unifying feature. In the "suspected stage", the SCMS is not present, but the severity of the injury or circumstances reveals the suspicion of SCMS. In this stage, HBOT is not indicated, but frequent neurocirculatory checks must recognize the progression to compartment syndrome. Increasing pain, hypesthesia, muscle weakness, discomfort with passive stretching of the toes/fingers, and/or tautness of the compartment's contents need to be evaluated. Muscle compartment tissue pressure measurements should be performed. If fasciotomy is not required, HBOT should be initiated to prevent progression to the "established stage". If pressure testing is not available in the "impending stage", three or more clinical findings are required for HBOT initiation. These clinical findings are listed in Figure 1 (20).

HBOT has also been indicated in the "impending stage" when the compartment pressures have been increasing with serial measurement, but the threshold level for fasciotomy has not yet been reached. In addition, the patient's Wellness score might be paired with compartment pressure measurements when deciding on HBOT (Figure 1, Table 2) (20).

In the "established stage", immediate fasciotomy is indicated. After fasciotomy, HBOT should be considered as an adjunctive therapy for wound management if significant residual problems remain. Post-fasciotomy HBOT indications include ischemic muscle, unclear demarcation between viable and non-viable tissue, massive swelling/prolonged (more than 6 hours) ischemia time, threatened skin flap or graft, residual neuropathy, and/or significant comorbidities as determined by the Wellness score (20).

3. Frostbite

The victims of the Maraş earthquake had to endure extreme climate during the winter. On February 6th, 2023, the lowest temperature was 0 °C and there was intermittent snowfall in the northern parts of the region affected by the earthquake. The air temperature dropped below 0 °C in the following days (34). While people were trying to survive with light clothes under rubble in winter, many other surviving people were left homeless and stayed in tents under freezing weather conditions. Hypothermia became a growing problem. We treated a frostbite injury in a victim of the Maraş earthquake using HBOT (Figure 2). Physicians should be aware of frostbite in earthquake victims, although it has been mainly reported in military populations and homeless people (35).

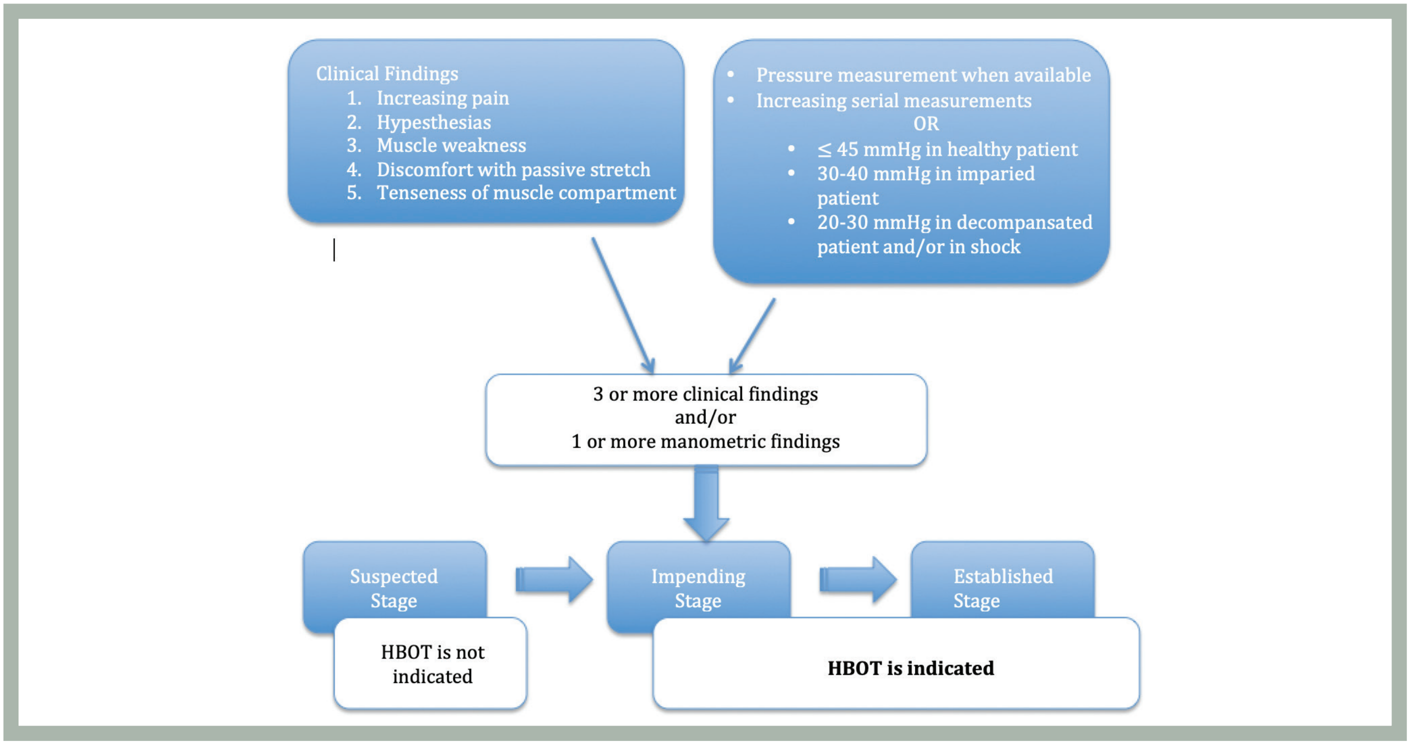


Figure 1. HBOT indication algorithm for SMCS

HBOT: Hyperbaric oxygen therapy, SMCS: Acute skeletal muscle compartment syndrome

Figure 2. Frostbite injury on the left foot in an earthquake victim

Frostbite is a localized cold thermal injury caused by exposure to low temperatures that cause ice crystal formation in tissues, damaging cell membranes and osmotically dehydrated cells (35). Indirect injury by cold-induced vasoconstriction increases blood viscosity, resulting in sludging of erythrocytes and thrombus formation. As a result, tissue hypoxia and inflammation occur. Further congestion and stasis result in circulatory collapse and endothelial plasma leakage with downrange tissue ischemia (36). Frostbite is another subgroup of acute traumatic peripheral ischemias in which HBOT may be a therapeutic option. There is a plausible mechanism of action that suggests effective treatment using HBOT. The evidence mainly includes animal studies and case reports (Table 4) (36,37,38,39,40). Only two case-controlled studies have been published (41,42,43). Magnan et al. (44) conducted a multicenter prospective single-arm study. Stage 3 or 4 frostbite patients whose medical care was initiated in the first 72 hours were included. Although 28 patients underwent HBOT and standard care with iloprost, 30 patients received only standardized frostbite treatment with iloprost. Combination of HBOT and iloprost was associated with higher benefits in patients with severe frostbite. The number of preserved segments was two-fold higher in the HBOT combination with iloprost-only group than in the iloprost group (mean of 13 preserved segments vs. 6), and the reduction of amputation was more significant in patients treated by HBOT combination with iloprost than in those treated by iloprost alone (41). In a multicenter retrospective cohort study, there was no statistically significant difference between the HBOT and non-HBOT groups regarding amputation characteristics. Hospital stay was longer in the HBOT group than in the non-HBOT group (42). To our knowledge, no earthquake-related frostbite injury case has been reported to be treated with HBOT in the existing literature.

4. Special Considerations for Earthquake Survivors During HBOT Procedures

HBOT has been successfully applied to earthquake survivors for several indications (2). Due to the massive destructive nature of earthquakes, numerous patients might be consulted for urgent HBOT in local hospitals. Hyperbaric physicians should be aware of the massive burden and have taken immediate precautions to ensure a carefully planned organization. In this respect, we will highlight some special considerations regarding HBOT applications in this patient group, summarized in Table 5.

a. Organization

Many patients were consulted for emergency HBOT from several hospitals and cities affected by the earthquake. This situation presented several challenges for clinicians. First, evaluating a patient from another hospital or city without performing a physical medical examination was compelling. Second, clinicians had to consider transportation risks and arrange other ongoing therapies such as hemodialysis and requirements such as intensive care unit (ICU) in the transferred hospital. Besides, hyperbaric chambers may not meet the HBOT need despite working 24 hours due to the patient capacity limit of the chambers. Moreover, many patients were on stretchers, resulting in less capacity for hyperbaric chambers. After the Maraş earthquake, patients seats inside the hyperbaric chamber were dismantled in most HBOT centers to make more field for more stretchers inside the hyperbaric chamber (Figure 3).

b. Technical Issues

Most patients required other therapies with medical devices continuously or for long durations, including vacuum-assisted closure (VAC) techniques, infusion pumps, and mechanical ventilation. Only HBOT-approved medical devices can be operated inside a hyperbaric chamber during sessions because of fire predisposition inside chambers (51). VAC therapies with special arrangements can be maintained without interruption during HBOT sessions. Many HBOT centers have HBOT-approved mechanical ventilators. All medical requirements should be discussed with a hyperbaric physician before treatment.

Table 4. Case reports and case series of frostbites treated with HBOT (35,43,44,45,46,47,48,49,50)

Authors	Patient no.	Etiology	Delay in HBOT	HBOT	Other Treatments	Outcome
Ghumman et al. (35) 2019	22	Alcohol intoxication and psychiatric illnesses	-	2.5 ATA, 90 min, 2 or 3 times daily, total HBOT sessions 3-43	Antiplatelet or anticoagulant therapy	In 50% of the cases requiring amputation, the final amputation level was more distal to the predicted level from pretreatment bone scans
Higdon et al. (43) 2015	1	Alcohol intoxication and falling unconscious in a snowy field	-	2.0 ATA, 90 min, 40 HBOT sessions	Tissue plasminogen activator therapy, abciximab	Of his six digits with extensive, deep frostbite, one digit eventually required partial amputation, and another had protracted osteomyelitis treated with intravenous antibiotics
Magnan et al. (44) 2022	1	Climbing (grade 3 frostbite of both hands)	3 days	HBOT daily for 3 weeks	Lioprost infusion for 7 days	No amputation required, able to climb again and play volleyball
Davis et al. (45) 2022	1	Climbing (8 digits of both hands; 5 of these were grade 3 frostbite)		2.0 ATA, 90 min, 32 HBOT sessions	Aspirin	Underwent amputation of three digits
Robins (46) 2019	1	Hiking (toes of both feet and plantar surface of left foot)	HBOT initiated 2 h from the estimated time of rewarming	2.4 ATA, 90 min, 13 HBOT sessions	Oral pentoxiphylline	At the 12-month follow-up, the patient had a durable healing, with complete recovery of sensation in the left foot and toes. Some surface sensory loss was reported
Kemper et al. (47) 2014	1	Climbing (1st toes of both feet)	21 days	2.5 ATA, 90 min, 19 HBOT sessions	-	No surgical intervention is required. The patients toes recovered almost completely. With a minor cosmetic defect and some impairments in flexion of the right. First digit
Lansdorp et al. (48) 2017	2	Hiking (both forefeet)	28 days	2.5 ATA 80 min, patient a received 25 HBOT sessions and Patient B received 30 HBOT sessions	Vasodilatators, pentoxiphyllin, LMWH, analgesic, antibiotics	Patient A: Only partial surgical amputation of the second toe on the right. Patient B: Both forefeet were surgically amputated
von Heimburg et al. (49) 2001	1	Working without gloves during a hunt in Poland (3rd-degree frostbite on 4 fingers of right and 2 fingers of left hand)	1 week	2.4 ATA 90 min, daily sessions, 14 sessions		Complete resolution. Only 2 finger nails were lost
Folio et al. (50) 2007	1	Climbing (all fingers of both hand)	2 weeks	21 HBOT sessions		All fingers recovered, except that one finger remained slightly misshapen. No amputation required. Normal neurological motor function and only mildly decreased sensation (hardly noticeable except under cold conditions) on the tip of the misshapen finger

HBOT: Hyperbaric oxygen therapy, ATA: Atmosphere absolute, h: Hour min: Minute

Table 5. Special Considerations for the HBOT

1. Organization	Planning
	Triage
	Transportation
	Multiple strecthers in the same HBOT session
2. Technical issues	HBOT-approved medical devices
	Continuing VAC during HBOT
3. Providing frequent HBOT sessions without delay in other required medical therapy/ interventions	Frequent blood transfusions
	Pain management
	Frequent surgeries/surgical debridements
	Long-lasting hemodialysis and hemofiltration
4. Adverse events and contraindications	Pulmonary barotrauma
	• Managing patients with chest trauma and chest tubes
	• Mechanical ventilation
	Continuing ICU requirements during HBOT sessions for critically ill patients
	• Mechanical ventilation
	• Monitorization
	• Inotropic support
	• Pain management
5. Therapy aims	Therapy aims
6. Phsycosocial aspects	Medical staff
	• Working full time, overwhelming schedule
	• Stress management
	Patients
	• claustrophobia
	• Reaching out to other family members
	• Approval for HBOT for unidentified child
	• Post-traumatic physicological problems

HBOT: Hyperbaric oxygen therapy, VAC: Vacuum-assisted closure, ICU: Intensive care unit

c. Providing Frequent HBOT Sessions without Delay for other Medical Therapies/Interventions

Earthquake survivors may need frequent surgical debridements, blood transfusions, and long-lasting hemodialysis or hemofiltrations. These interventions cannot be postponed or interrupted for HBOT sessions. Note that one HBOT session lasts for two hours. Therefore, providing the recommended frequent HBOT schedule for these patients might be challenging. Physicians must carefully evaluate patients' clinical status and therapy aims.

d. Adverse Events and Contraindications

HBOT has several complications with varying degrees of seriousness. Pulmonary barotrauma is a rare but one of the most significant complications of HBOT. Overdistension and rupture of alveoli due to gas trapping can result in pneumothorax, pneumomediastinum, or even arterial gas embolism (20). In this respect, significant air trapping in the lungs, or anything that leads to pulmonary overinflation and a history of spontaneous pneumothorax, are concerning for hyperbaric physicians (20,52). Nevertheless, untreated tension pneumothorax is the only absolute contraindication for HBOT (53). Pulmonary barotrauma is also a feared complication of mechanical ventilation, particularly in patients with severe underlying lung disease (54). Cakmak et al. (55) reported tension pneumothorax in an intubated and mechanically ventilated earthquake survivor during the decompression phase of the seventh HBOT session. The patient was successfully treated with a chest tube. In addition, earthquake victims may have accompanying significant thoracic injuries (56). In this respect, earthquake victims' pulmonary examinations should be carefully performed before HBOT. We applied HBOT to many patients with accompanying thoracic injuries without complications (Figure 4).

Continuing care for ICU patients who may require mechanical ventilation, inotropic support, and continuous monitoring inside a hyperbaric chamber is another challenge for hyperbaric physicians. Precautions should be taken concerning the hyperbaric chamber-approved medical equipment, required drugs, adverse events related to drugs applied during HBOT and patient-ventilator asynchrony, or other symptoms such as agitation and hallucinations related to inadequate sedation. In addition, epileptic seizures might be reported as related to oxygen toxicity. Physicians should be fully prepared for severe shocks despite the use of inotropic drugs and cardiopulmonary arrests (57).

Figure 3. Four patients with stretchers were receiving HBOT in the multiplace chamber at Gülhane Training and Research Hospital

HBOT: Hyperbaric oxygen therapy

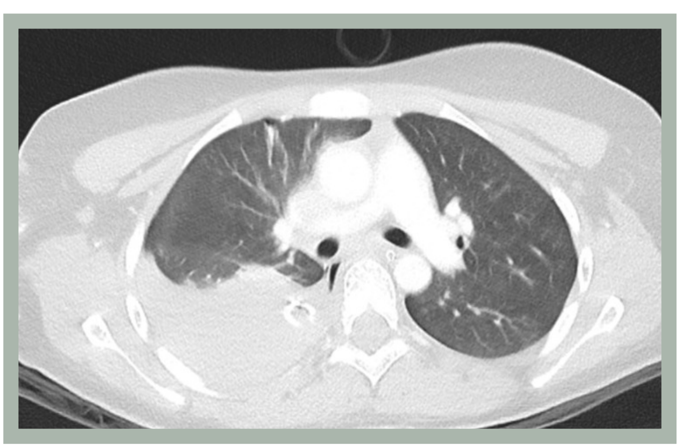


Figure 4. Computed tomography image of the chest of an earthquake victim. Hemopneumothorax in right lung and minimal pneumothorax in left lung

e. Therapy Aims

Hyperbaric physicians should determine their final HBOT expectations at the beginning of therapy. In this regard, the HBOT schedule can be organized effectively. Aktas (2) defined the therapy aims as follows:

(i) To save and conserve all tissues and functions,

(ii) To save all tissues,

(iii) To save from amputation,

(iv) To treat late complications,

(v) To save only one life (2).

f. Psychosocial Aspects

Working full-time with an overwhelming schedule can be challenging for medical staff's physical and mental health. In addition, significant worries about their families and continuous aftershocks could be distractive (2). Stress management by medical staff should be considered.

On the other hand, patients may be unwilling to attend HBOT sessions because of claustrophobia after extraction from rubbles. Post-traumatic psychiatric problems may arise. In addition, children patients without family members may be agitated during treatments.

Conclusion

In severe earthquakes, in addition to many casualties, the number of serious trauma patients is usually very high. Many crush injuries and compartment syndrome cases happen because of being under debris, and limb frostbite because of being under debris for a long time, depending on the temperature in the earthquake area. Approaching the treatment of these patients from a multidisciplinary perspective and planning their treatment is important in preventing limb loss, shortening hospital stays, and achieving functional extremities. Although limited publications support the use of HBOT in addition to surgical interventions, many experts report that starting HBOT as soon as possible has positive benefits for patients.

The workload of centers providing HBOT increases significantly during these periods. The fact that most patients are on stretchers limits the number of patients who can receive HBOT. It is important to plan the treatment of patients and act in coordination with the clinics where the patients are followed.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: K.Ö.K., A.A., Design: K.Ö.K., A.A., Data Collection or Processing: K.Ö.K., A.A., Analysis or Interpretation: K.Ö.K., A.A., Literature Search: K.Ö.K., A.A., Writing: K.Ö.K., A.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Bartels SA, VanRooyen MJ. Medical complications associated with earthquakes. Lancet 2012;379:712.
2. Aktas S. Advances in the treatment of earthquake victims in Turkey: an editorial perspective. Undersea Hyperb Med 2015;42:1-3.
3. Dougherty JE. The role of hyperbaric oxygen therapy in crush injuries. Crit Care Nurs Q 2013;36:299-309.
4. Wattel F, Mathieu D, Nevière R, Bocquillon N. Acute peripheral ischaemia and compartment syndromes: a role for hyperbaric oxygenation. Anaesthesia 1998;53(Suppl 2):63-65.
5. Available from: https://www.uptodate.com/contents/severe-crush-injury-in-adults?search=crush%20injury&source=search_result&selectedTitle=1~129&usage_type=default&display_rank=1
6. Erek E, Sever MS, Serdengeçti K, et al. An overview of morbidity and mortality in patients with acute renal failure due to Crush syndrome: the Marmara earthquake experience. Nephrol Dial Transplant 2002;17:33-40.
7. Smith G, Stevens J, Gritfiths JC. Near-avulsion of foot treated by replacement and subsequent prolonged exposure of patient to oxygen at two atmospheres pressure. Lancet 1961;2:1122-1123.
8. Székely O, Szánto G, Takats A. Hyperbaric oxygen therapy in injured subjects. Injury 1973;4:294-300.
9. Monies-Chass I, Hashmonai M, Hoere D, Kaufman T, Steiner E, Schramek A. Hyperbaric oxygen treatment as an adjuvant to reconstructive vascular surgery in trauma. Injury 1977;8:274-277.
10. Bouachour G, Cronier P, Gouello JP, Toulemonde JL, Talha A, Alquier P. Hyperbaric oxygen therapy in the management of crush injuries: a randomized double-blind placebo-controlled clinical trial. J Trauma 1996;41:333-339.
11. Millar IL, Lind FG, Jansson KÅ, et al. Hyperbaric oxygen for lower limb trauma (HOLLT): an international multi-centre randomised clinical trial. Diving Hyperb Med 2022;52:164-174.
12. Yıldız S, Özkan S, Dündar K, Ay H, Kıralp MZ, Pehlivan Ö. Hyperbaric oxygen therapy in crush injuries after 17th August earthquake in Marmara. Gulhane Med J 2004;46:194-199.
13. Oley MH, Oley MC, Noersasongko AD, et al. Hyperbaric oxygen therapy in low extremity trauma: a case series. Ann Med Surg (Lond) 2022;78:103896.
14. Kemmer A. Crush injury and other acute traumatic ischemia. In: Mathieu D, editor. Handbook on Hyperbaric Medicine. Netherlands. Springer; 2006. p. 305-327.
15. Available from: https://www.uptodate.com/contents/acute-compartment-syndrome-of-the-extremities#:~:text=Acute%20compartment%20syndrome%20(ACS)%20is%20a%20surgical%20emergency%20–%20ACS,ACS%20is%20a%20surgical%20emergency
16. Reis ND, Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome: with special reference to earthquake casualties. J Bone Joint Surg Br 2005;87:450-453.
17. Görmeli G, Görmeli C, Güner S, Ceylan M, Dursun R. A clinical analysis of patients undergoing fasciotomy who experienced the 2011 Van earthquake. Jt Dis Relat Surg 2012;23:156-160.
18. Duman H, Kulahci Y, Sengezer M. Fasciotomy in crush injury resulting from prolonged pressure in an earthquake in Turkey. Emerg Med J 2003;20:251-252.
19. Available from: https://www.uptodate.com/contents/lower-extremity-fasciotomy-techniques?search=fasciotomy&source=search_result&selectedTitle=1~69&usage_type=default&display_rank=1
20. Strauss MB: chapter 6 the role of hyperbaric oxygen for acute traumatic ischemias; in Weaver LK (ed): Hyperbaric oxygen therapy indication. 13th ed. North Palm Beach, FL: Best Publishing Company, 2014, pp 135-151.
21. Strauss MB, Hargens AR, Gershuni DH, et al. Reduction of skeletal muscle necrosis using intermittent hyperbaric oxygen in model compartment syndrome. J Bone Joint Surg 1983;65:656-662.
22. Skyhar MJ, Hargens AR, Strauss MB, Gershuni DH, Hart GB, Akeson WH. Hyperbaric oxygen reduces edema and necrosis of skeletal muscle in compartment syndromes associated with hemorrhagic hypotension. J Bone Joint Surg Am 1986;68:1218-1224.
23. Strauss MB, Hargens AR, Gershuni DH, Hart GB, Akeson WH. Delayed use of hyperbaric oxygen for treatment of a model anterior compartment syndrome. J Orthop Res 1986;4:108-111.
24. Bartlett RL, Stroman RT, Bnickels M, Kalns JE, Fuhrman CT, Piepmeier EH. Rabbit model of the use of fasciotomy and hyperbaric oxygen in the treatment of compartment syndrome. Undersea Hyperb Med 1998;25(Suppl):29.

25. Aydin F, Aktaş S, Olgaç V, Mezdeği A, Karamülsel S. The effects of hyperbaric oxygen and surgical decompression in experimental compartment syndrome. Ulus Travma Acil Cerrahi Derg 2003;9:176-182.
26. Lee S, Han J, Heo T. Successful adjunctive treatment of compartment syndrome due to acute isocyanate inhalation using hyperbaric oxygen therapy: case report. Undersea Hyperb Med 2020;47:455-459.
27. Han S, Lee Y, Lim H, et al. Compartment syndrome in the forearm related to carbon monoxide intoxication: case report. Undersea Hyperb Med 2018;45:689-693.
28. Mendes AF Jr, Neto JDM, Heringer EM, de Simoni LF, Pires DD, Labronici PJ. Hyperbaric oxygen therapy as treatment for bilateral arm compartment syndrome after CrossFit: case report and literature review. Undersea Hyperb Med 2018;45:209-215.
29. Al B, Subası M, Karsli B, Yarbil P, Zengin S. Compartment syndrome on a patient's forearm related to carbon monoxide poisoning. Am J Emerg Med 2012;30:2104.
30. Hoy G, Hasenkam C, Fock A, McLean C. hyperbaric oxygen as an adjunctive therapy postfasciotomy for unilateral supraspinatus rhabdomyolysis and compartment syndrome. Case Rep Orthop 2018;2018:5485767.
31. Abdullah MS, Al-Waili NS, Butler G, Baban NK. Hyperbaric oxygen as an adjunctive therapy for bilateral compartment syndrome, rhabdomyolysis and acute renal failure after heroin intake. Arch Med Res 2006;37:559-562.
32. Fitzpatrick DT, Murphy PT, Bryce M. Adjunctive treatment of compartment syndrome with hyperbaric oxygen. Mil Med 1998;163:577-579.
33. Korambayil PM, Ambookan PV, Abraham SV, Ambalakat A. A multidisciplinary approach with hyperbaric oxygen therapy improve outcome in snake bite injuries. Toxicol Int 2015;22:104-109.
34. Available from: https://www.aa.com.tr/tr/gundem/kahramanmaras-merkezli-depremden-etkilenen-10-ilin-hava-durumu/2807405
35. Ghumman A, St Denis-Katz H, Ashton R, Wherrett C, Malic C. Treatment of frostbite with hyperbaric oxygen therapy: a single center's experience of 22 cases. Wounds 2019;31:322-325.
36. Robins M, Hendriksen S, Cooper JS. Hyperbaric management of frostbite. [Updated 2022 Aug 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448115/
37. Gage AA, Ishikawa H, Winter PM. Experimental frostbite. The effect of hyperbaric oxygenation on tissue survival. Cryobiology 1970;7:1-8.
38. Gage AA, Ishikawa H, Winter PM. Experimental frostbite and hyperbaric oxygenation. Surgery 1969;66:1044-1050.
39. Okuboye JA, Ferguson CC. The use of hyperbaric oxygen in the treatment of experimental frostbite. Can J Surg 1968;11:78-84.
40. Hardenbergh E. Hyperbaric oxygen treatment of experimental frostbite in the mouse. J Surg Res 1972;12:34-40.
41. Magnan MA, Gayet-Ageron A, Louge P, et al. Hyperbaric oxygen therapy with iloprost improves digit salvage in severe frostbite compared to iloprost alone. Medicina (Kaunas) 2021;57:1284.
42. Cooperman SR, Kruse D, Sachs BD, Cornett B, Choi YJ. Evaluating the efficacy of hyperbaric oxygen therapy in digital frostbite. J Foot Ankle Surg 2023:S1067-2516.
43. Higdon B, Youngman L, Regehr M, Chiou A. Deep frostbite treated with hyperbaric oxygen and thrombolytic therapies. Wounds 2015;27:215-223.
44. Magnan DM, Gelsomino M, Louge P, Pignel R. Successful delayed hyperbaric oxygen therapy and iloprost treatment on severe frostbite at high altitude. High Alt Med Biol 2022;23:294-297.
45. Davis A, Sinopoli B, Mann N, Stenbit AE. A photographic case of frostbite treated with delayed hyperbaric oxygen therapy. High Alt Med Biol 2022;23:194-197.
46. Robins M. Early treatment of frostbite with hyperbaric oxygen and pentoxifylline: a case report. Undersea Hyperb Med 2019;46:521-526.
47. Kemper TC, de Jong VM, Anema HA, van den Brink A, van Hulst RA. Frostbite of both first digits of the foot treated with delayed hyperbaric oxygen:a case report and review of literature. Undersea Hyperb Med 2014;41:65-70.
48. Lansdorp CA, Roukema GR, Boonstra O, Dokter J, van der Vlies CH. Delayed treatment of frostbite with hyperbaric oxygen: a report of two cases. Undersea Hyperb Med 2017;44:365-369.
49. von Heimburg D, Noah EM, Sieckmann UP, Pallua N. Hyperbaric oxygen treatment in deep frostbite of both hands in a boy. Burns 2001;27:404-408.
50. Folio LR, Arkin K, Butler WP. Frostbite in a mountain climber treated with hyperbaric oxygen: case report. Mil Med 2007;172:560-563.
51. Jain KK: Chapter 7 Hyperbaric Chambers: Equipment, Technique, and Safety in Jain KK: Textbook of Hyperbaric Medicine. Switzerland, Springer International Publisher, 2017, pp 61-78.
52. Sadri RA, Cooper JS. Hyperbaric Complications. [Updated 2022 Sep 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459191/
53. Jain KK: Chapter 8 Indications, Contraindications, and Complications of HBO Therapy in Jain KK: Textbook of Hyperbaric Medicine. Switzerland, Springer International Publisher, 2017, pp 79-84.
54. Anzueto A, Frutos-Vivar F, Esteban A, et al. Incidence, risk factors and outcome of barotrauma in mechanically ventilated patients. Intensive Care Med 2004;30:612-619.
55. Cakmak T, Battal B, Kara K, et al. A case of tension pneumothorax during hyperbaric oxygen therapy in an earthquake survivor with crush injury complicated by ARDS (adult respiratory distress syndrome). Undersea Hyperb Med 2015;42:9-13.
56. Ozdoğan S, Hocaoğlu A, Cağlayan B, Imamoğlu OU, Aydin D. Thorax and lung injuries arising from the two earthquakes in Turkey in 1999. Chest 2001;120:1163-1166.
57. Bessereau J, Aboab J, Hullin T, et al. Safety of hyperbaric oxygen therapy in mechanically ventilated patients. Int Marit Health 2017;68:45-51.

REVIEW

DOI: 10.4274/csmedj.galenos.2023.2023-9-3

CSMJ

Cam and Sakura Med J 2023;3(Suppl 1):42-47

Prevention of Infectious Diseases after an Earthquake

Ayşe Baran, Ali Özer

İnönü University Faculty of Medicine, Department of Public Health, Malatya, Turkey

ABSTRACT

The earthquake in Kahramanmaraş, Turkey, on February 6, 2023, was recorded as one of the most severe earthquakes recently. Because of the magnitude of the intensity of the earthquake and its coverage of many provinces, it had devastating effects. In addition to the impact of the disaster after the quake, the emergence and spread of infectious diseases were facilitated by insufficient safe water, housing problems, inadequate nutrition, inadequate hygiene conditions, and many individuals living in public areas. In this context, respiratory tract infections, gastrointestinal infections, skin infections, and vector-borne infections are more common after disasters. Necessary measures should be taken to establish an effective surveillance system for preventing and protecting infectious diseases after the earthquake, plan new settlements, continue immunization services, access safe water, and provide adequate and balanced nutrition, sanitation, vector control, and health education.

Keywords: Earthquakes, communicable diseases, infections, disaster

CAM & SAKURA MEDICAL JOURNAL

Introduction

Globally, between 2000 and 2019, 7348 major disaster events caused serious economic losses, affecting 4.2 billion people in total, of which 1.23 million people lost their lives, an increase of approximately twenty times compared to 1980-1999 (1). In this context, the major earthquakes in eastern Turkey are examined. The Erzincan earthquake, with a magnitude of 7.9 on December 27, 1939, caused 32.962 deaths (2). The Van earthquake, which was 7.1 in eastern Turkey on October 23, 2011, caused 604 deaths, 4152 injuries, and 32,938 people to be affected (3). Finally, on February 6, 2023, two earthquakes with a magnitude of 7.7 in the center of Pazarcık in Kahramanmaraş and 7.6 in the center of Elbistan occurred (4). The last two earthquakes in Kahramanmaraş were recorded as the most severe earthquakes since 1939 (5). After the Kahramanmaraş-centered earthquakes, approximately 26 million individuals (5 million in the vulnerable group) were affected (6). Approximately 50 thousand deaths occurred in Turkey, and 107 thousand people were injured (7). After the earthquake, 298 thousand buildings were destroyed, and 3 million people settled in other provinces temporarily or permanently (7).

In addition to the physical and psychological effects that occur depending on the magnitude of the disaster experienced after the earthquake, the restriction of access to safe drinking and utility water, deterioration of sanitation and hygiene conditions, infrastructure damage, and traumatic injuries lead to the emergence and spread of

Address for Correspondence: Ayşe Baran MD, İnönü University Faculty of Medicine, Department of Public Health, Malatya, Turkey
E-mail: abaran88@hotmail.com **ORCID ID:** orcid.org/0000-0002-0591-2936
Received: 12.09.2023 **Accepted:** 15.12.2023

infectious diseases in the society (8). Effectively responding to the needs of disaster-affected populations requires an accurate communicable disease risk assessment. The effective use of humanitarian aid depends on implementing priority interventions based on this risk assessment (9). In public health emergencies such as earthquakes, several factors can influence the emergence and spread of infectious diseases. These include the following: prevalence of endemic and epidemic diseases in the affected area; living conditions of the affected population, including the number, size, location, and density of the affected settlements; availability of safe water and adequate sanitation facilities; nutritional and immunization status of individuals; level of access to health services; existence of an effective surveillance system; and effective management of emerging infections (Table 1) (10). According to a systematic review and meta-analysis of the incidence of post-earthquake infectious diseases, gastrointestinal and hepatic infections were most common after the earthquake, with 163.4 cases per 100,000 people. The second highest rate is skin infections, with 84.5 cases per 100,000 people, followed by respiratory tract infections, with 9.9 cases per 100.000 people. Central nervous system infections are seen least frequently, with 0.5 points per 100.000 people (11).

During the acute period after a natural disaster, non-specific infections (such as tetanus, gas gangrene, and wound infections) and respiratory system infections (such as influenza, measles, rubella, and diphtheria) occur due to trauma. In the sub-acute period, after individuals are evacuated to public living areas and live in crowded environments, insufficient ventilation and unhealthy conditions, skin infections (such as scabies, and anthrax), viral infections (such Japanese encephalitis) because of close contact between people, vector-borne infections (rickettsia, malaria, typhus) and gastrointestinal infections (norovirus, cholera, typhoid, food poisoning) occur. In the later period after the disaster, tuberculosis, other viral infections (Hepatitis A, E, polio), and various animal-borne infections (such as rabies leptospirosis) were observed (13,14).

Infectious diseases in survivors after the earthquake are caused by disruption or complete cessation of infection control activities. The increase in transmission increases the risk of post-disaster infection because of infection control and routine surveillance studies, changes in the sensitivity of society, and new factors that have emerged. Registration and notification are essential for effective infectious disease management. All employees working in the region should be informed about how and where to make these statements. The information obtained should be evaluated in a short time. Considering the endemic diseases and immunization rates in the disaster region, diseases that may cause epidemics should be determined, and precautions should be taken to control these diseases. Standard case definitions should be made and explained employees regarding possible cases. The quantities and needs of materials such as vaccines, drugs, and oral rehydration fluid to be used in an emergency should be determined, and where they can be obtained if necessar. It should be ensured that the cold chain is not disrupted (15).

In the days following the earthquake, patients and their possible contacts should be monitored, and infection control measures should be taken. Especially for diseases transmitted by contaminated water and food. Therefore, adequate hygiene conditions should be provided for water and food, clean water supply and storage, proper removal of feces and wastes, and washing hands with soap and water (16).

It has been stated that 15 hospitals were partially or completely damaged in the acute period after the Kahramanmaraş earthquakes (6). After an earthquake, structural damage in health facilities causes delays in managing and treating infectious disease cases when the emergency response and subsequent processes are not repaired and

Table 1. Groups of communicable diseases preventable according to post-earthquake precautions (12)

Precaution taken	Disease group
Settlement planning	Diarrheal diseases and respiratory tract infections
Safe water	Diarrheal diseases and typhoid fever
Sanitation	Diarrheal diseases, vector-borne diseases, and scabies
Malnutrition	Tuberculosis, measles, and respiratory tract infections
Vaccination	Measles, meningitis, yellow fever, Japanese encephalitis, diphtheria, tetanus
Vector control	Malaria, leishmaniasis, dengue, and Japanese encephalitis
Personal hygiene	Typhus, relapsing fever
Personal protection	Malaria, leishmaniasis
Health education	Sexually transmitted infections and respiratory tract infections

service delivery is not continued. For this reason, it should be ensured that health institutions continue to provide evaluations as soon as possible after the earthquake (17). In this context, the infectious diseases frequently encountered after the earthquake and the methods of protection will be examined.

Skin Infections and Prevention

Risks arising from living together in collective living areas and camps: inadequate ventilation and inappropriate hygienic conditions due to close contact between people. Because of these conditions, scabies from skin infections can occur. Other family members and close contacts should be treated when scabies occurs, and various medical treatments should be used. In addition, the sheets, pillows, and clothes used by the person should be washed and dried at high temperatures. If these items cannot be washed, they should be used after being stored in a closed plastic bag for a week. Treating scabies as soon as possible and isolating contacts is the best way to prevent outbreaks (18).

Gastrointestinal Infections and Prevention

Gastrointestinal infections are the most common infectious diseases after earthquakes and have a high mortality rate in risky groups (11,19). Gastrointestinal infections have been reported after many earthquakes in Turkey and around the world from the past to the present (20,21,22,23,24,25,26,27). Many pathogens, including *Shigella* spp., *Salmonella* spp., *Escherichia coli, Campylobacter* spp., *Vibrio cholarea, Yersinia enterocolytica,* and viral infection agents (hepatitis A, E, rotavirus, norovirus, and adenovirus) are causative agents in these infections (28,29). The most important factors in water-borne infections and epidemics caused by infections after earthquakes are the mixing of pollutants and infectious agents into the water supply and network due to fractures in the ground floor during earthquakes (29). In this respect, various recommendations are offered for the supply of safe water to the community in the acute period after the earthquake. These recommendations include the following:

1. Provide packaged water, if possible, to the community during the acute period,

2. If the acute situation gets better, use the mains water with permanent solutions as soon as possible, first by chlorination; if this cannot be achieved, boil it, on the condition that it is constantly monitored.

3. If the network system cannot be used, chlorination or filtration techniques should be provided to appropriate families by providing necessary training after safe and individual storage, provided that local conditions are considered (29).

Immunization against hepatitis A, which is a gastrointestinal infection factor, is carried out regularly in Turkey by adding it to the childhood vaccination calendar as of 2012 (30). In this context, inadequate access to safe water and hygiene conditions, especially in regions with low vaccination rates, should be considered and caution should be exercised.

Respiratory Tract Infections and Prevention

Respiratory tract infection is another infection that is frequently encountered in the short term after an earthquake. Adverse weather in temporary settlements where the crowding factor is effective, where most people affected by the earthquake live, inadequate ventilation and heating, close contact, inadequate nutrition, and inadequate personal hygiene are among the risk factors for respiratory infectious diseases (17,31,32,33,34,35). Mortality may increase due to pneumonia, especially in risk groups such as children, the elderly, and individuals with chronic diseases. Therefore, providing temporary shelter and housing assistance quickly after the earthquake, making primary health care services functional, and ensuring effective surveillance of emerging infectious diseases are vital for the livelihoods of the displaced population (36). In addition, considering that coronavirus disease-2019 (COVID-19) is still widespread and the season is suitable for the spread of influenza, immunization studies should be conducted in risk groups. To protect against these infections, wearing a surgical mask, washing hands frequently, and, if possible and if the conditions are suitable, vaccination of unvaccinated individuals (for diphtheria, whooping cough, measles, COVID-19, and influenza) or chemoprophylaxis (for meningococcal meningitis, diphtheria, and whooping cough) may be recommended.

Other Infections and Prevention

Tetanus and wound infections occur with traumas after earthquakes. After the Indonesian earthquake in 2004-2006, many tetanus cases were observed, especially in regions with lower vaccination rates (37). Case fatality rates in these cases ranged from 18.9% to 36.6%, and trauma was found to be the main factor in the occurrence of these cases. Poor access to health services due to limited transportation or inadequate hospital facilities, low vaccination coverage, and low awareness of tetanus risk, as the main causes of case fatality rates and case occurrence, contributed to the delay for treating patients and the progression of cases (37,38). Tetanus is prevented to a great extent by effective vaccination. Because of impaired skin integrity because of trauma, the wound site should be properly cleaned, and vaccination and, if necessary, antibiotic therapy should be initiated to prevent secondary infections (39). Therefore, post-earthquake tetanus cases can be prevented by increasing vaccination coverage, improving wound care treatment, and establishing a regular surveillance system, in addition to good disaster management practices and supportive care in line with national guidelines. In addition, public health education should be provided to increase awareness about reducing the risk of tetanus (12).

Vector-borne diseases may become more common in the post-earthquake period because of the changing contact patterns between individuals, pathogens, and vectors. Individuals can become infected by direct contact with rodents, pets, livestock, and infected animal shelters or by exposure to water, food, or soil contaminated with various body fluids, such as the urine of infected animals. The increased frequency of contact of these vectors with earthquake victims or various aid and rescue teams in the earthquake zone leads to diseases. The vector types commonly seen in these regions should first be determined to protect against these infections, and precautions should be taken accordingly (40). The local distribution of such creatures should be examined, regional breeding areas and environmental variables should be determined, and vectors should be dealt with accordingly. In this struggle, eliminating poor hygiene conditions, cleaning stagnant water bodies, providing sufficient potable water, and disposing of garbage and waste are important (41). In addition, importance should be given to the surveillance system against vector-borne diseases in these regions. Health personnel working in these regions should be informed about the symptoms of the diseases, methods of transmission, management of such cases, and what needs to be done to control and prevent these diseases (42).

In natural disasters, sexually transmitted infections caused by viruses such as HIV, *N. gonorrhea, T. pallidum, Chlamydia* spp., and Herpes simplex type 2 may occur (43). In this regard, the community should be informed about protection measures against sexually transmitted infections in the earthquake region, and protective measures should be taken.

Conclusion

Epidemiologically, the connection and interaction between the three elements play a role in the emergence of infectious diseases. These include a pathogenic agent, a susceptible host, and a suitable environment in which the pathogen and host encounter each other (44). Considering the post-earthquake period, the risk increases with the emergence of facilitating factors. To protect against these risks, precautions should be taken by targeting three elements. In this respect, the following recommendations should be considered.

An effective surveillance system for the prevention and protection of infectious diseases expected to emerge after the earthquake, accurate planning of settlements, continuation of immunization without interruption, provision of safe drinking and potable water, sanitation, vector control, and health education should be provided.

- New settlements should be planned with high population density and not be crowded, away from areas at risk of infectious diseases, and chosen in an area with easy access to clean water.
- The problem of safe drinking and potable water due to damage and contamination of water supply systems and resources must be resolved.
- Due to the lack of personal hygiene materials, individuals should be provided with adequate personal hygiene products.
- Adequate nutrition of individuals should be ensured by supplying the required food products.
- Heating and ventilation systems should be installed in shelter areas, which are basic needs.
- In order not to disrupt the provision of health services, health units should be established in accommodation areas as soon as possible.
- To prevent the spread and emergence of rodent/vector infestation and infectious diseases, waste must be appropriately disposed of, and vector control must be ensured.
- Individuals exposed to disasters should be informed about the methods of infection and control measures.
- A data collection system appropriate to the conditions in the disaster area should be established, and the data should be analyzed regularly.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: A.B., A.Ö., Design: A.B., A.Ö., Data Collection or Processing: A.B., A.Ö., Analysis or Interpretation: A.B., A.Ö., Literature Search: A.B., A.Ö., Writing: A.B., A.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. United Nations Office for Disaster Risk Reduction. The human cost of disasters: an overview of the last 20 years (2000-2019). Available from: https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019 Accessed July 26, 2023.
2. Turkish Ministry of Environment, Urbanization and Climate Change. 1939 Erzincan earthquake. Available from: https://erzincan.csb.gov.tr/1939-erzincan-depremi-haber-16203 Accessed August 21, 2023.
3. Centre for Research on the Epidemiology of Disasters (CRED) EM-DAT—The International Disaster Database. Available from: https://public.emdat.be/ Accessed August 7, 2023.
4. Ministry of Interior Disaster and Emergency Management Presidency. About Earthquakes In Kahramanmaraş – 34. Available from: https://www.afad.gov.tr/kahramanmarasta-meydana-gelen-depremler-hk-34 Accessed July 20, 2023.
5. Coordination of Humanitarian Affairs. Earthquake: Türkiye and north-west Syria Flash Update No. 1 As of 6 February 2023 Available from: https://reliefweb.int/report/turkiye/earthquake-turkiye-and-north-west-syria-flash-update-no-1-6-february-2023 Accessed July 18, 2023.
6. World Health Organization . Earthquake response in Türkiye and Whole of Syria. Available from: https://cdn.who.int/media/docs/default-source/documents/emergencies/2023/who_flashappeal_earthquakeresponse_11-feb-2023.pdf?sfvrsn=94d4de2a_1 Accessed July 19, 2023.
7. Coordination of Humanitarian Affairs Türkiye Earthquake 2023 Humanitarian Response Overview. Available from: https://reliefweb.int/report/turkiye/turkiye-earthquake-2023-humanitarian-response-overview-17-may-2023 Accessed July 20, 2023.
8. Abbara A, Zakieh O, Rayes D, et al. Weaponizing water as an instrument of war in Syria: impact on diarrhoeal disease in Idlib and Aleppo governorates, 2011-2019. Int J Infect Dis 2021;108:202-208.
9. Watson JT, Gayer M, Connolly MA. Epidemics after natural disasters. Emerg Infect Dis 2007;13:1-5.
10. Ergönül Ö, Keske Ş, Ksinzik A, et al. The challenges in the monitoring of infectious diseases after the earthquake in Türkiye in 2023. Lancet Infect Dis 2023;23:482-488.
11. Najafi S, Akahavan Rezayat A, Beyzaei SF, et al. Incidence of infectious diseases after earthquakes: a systematic review and meta-analysis. Public Health 2022;202:131-138.
12. Connolly MA, Gayer M, Ryan MJ, Salama P, Spiegel P, Heymann DL. Communicable diseases in complex emergencies: impact and challenges. Lancet 2004;364:1974-1983.
13. Izumikawa K. Infection control after and during natural disaster. Acute Med Surg 2019;6:5-11.
14. Gündüz Cebeci K, Akın L. Deprem sonrası bulaşıcı hastalık kontrolü. HÜTF Halk Sağlığı Anabilim Dalı Deprem Kaynaklı Afetlere Yönelik Toplum İçin Bilgilendirme Dizisi 2023/4. Available from: http://www.halksagligi.hacettepe.edu.tr/ Accessed August 1, 2023.
15. World Health Organization. Communicable diseases following natural disasters. Risk assessment and priority interventions Switzerland: Genava, 2006 Available from: https://www.who.int/publications/i/item/communicable-diseases-following-natural-disasters Accessed July 12, 2023.
16. Akın L. Bulaşıcı hastalıkların kontrolü. Güler Ç, Akın L, eds. Halk Sağlığı Temel Bilgiler. 3. Ankara: Hacettepe Üniversitesi Yayınları; 2015, p. 1350-1454.
17. Mavrouli M, Mavroulis S, Lekkas E, Tsakris A. The impact of earthquakes on public health: a narrative review of infectious diseases in the post-disaster period aiming to disaster risk reduction. Microorganisms 2023;11:419.
18. World Health Organization. Scabies. Available from: https://www.who.int/news-room/fact-sheets/detail/scabies Accessed August 15, 2023.
19. Kawano T, Hasegawa K, Watase H, Morita H, Yamamura O. Infectious disease frequency among evacuees at shelters after the great eastern Japan earthquake and tsunami: a retrospective study. Disaster Med Public Health Prep 2014;8:58-64.
20. Vahaboglu H, Gundes S, Karadenizli A, et al. Transient increase in diarrheal diseases after the devastating earthquake in Kocaeli, Turkey: results of an infectious disease surveillance study. Clin Infect Dis 2000;31:1386-1389.
21. Oztürk CE, Sahin I, Yavuz T, Oztürk A, Akgünoğlu M, Kaya D. Intestinal parasitic infection in children in post-disaster situations years after earthquake. Pediatr Int 2004;46:656-662.
22. Sencan I, Sahin I, Kaya D, Oksuz S, Yildirim M. Assessment of HAV and HEV seroprevalence in children living in post-earthquake camps from Düzce, Turkey. Eur J Epidemiol 2004;19:461-465.
23. Karadenizli A, Gurcan S, Kolayli F, Vahaboglu H. Outbreak of tularaemia in Golcuk, Turkey in 2005: report of 5 cases and an overview of the literature from Turkey. Scand J Infect Dis 2005;37:712-716.
24. Kaya AD, Ozturk CE, Yavuz T, Ozaydin C, Bahcebasi T. Changing patterns of hepatitis A and E sero-prevalences in children after the 1999 earthquakes in Duzce, Turkey. J Paediatr Child Health 2008;44:205-207.
25. Chen KT, Chen WJ, Malilay J, Twu SJ. The public health response to the Chi-Chi earthquake in Taiwan, 1999. Public Health Rep 2003;118:493-499.
26. Yorifuji T, Sato T, Yoneda T, et al. Disease and injury trends among evacuees in a shelter located at the epicenter of the 2016 Kumamoto earthquakes, Japan. Arch Environ Occup Health 2018;73:284-291.
27. Suvak B, Dulger AC, Suvak O, Aytemiz E, Kemik O. The prevalence of helicobacter pylori among dyspeptic patients in an earthquake-stricken area. Clinics (Sao Paulo) 2015;70:69-72.
28. Charles M, Delva GG, Boutin J, et al. Importance of cholera and other etiologies of acute diarrhea in post-earthquake Port-au-Prince, Haiti. Am J Trop Med Hyg 2014;90:511-517.

29. Lantagne D, Clasen T. Assessing the implementation of selected household water treatment and safe storage (HWTS) methods in emergency settings. Technical Report. London: London School of Hygiene and Tropical Medicine; 2010. Available from: https://researchonline.lshtm.ac.uk/id/eprint/404
30. TC. Minister of Health. What is Hepatitis A Disease? Available from: https://asi.saglik.gov.tr/liste/3-hepatit-a-hastal%C4%B1%C4%9F%C4%B1-nedir.html Accessed July 31, 2023.
31. Wang J, Ding H, Lv Q, et al. 2015 Nepal Earthquake: Analysis of Child Rescue and Treatment by a Field Hospital. Disaster Med Public Health Prep 2016;10:716-719.
32. Giri BR, Chapagain RH, Sharma S, Shrestha S, Ghimire S, Shankar PR. Effect of the 2015 earthquake on pediatric inpatient pattern at a tertiary care hospital in Nepal. BMC Pediatr 2018;18:28.
33. Shrestha D, Shrestha MK, Raya GB, et al. A 14-year-old girl presenting with tuberculous intestinal perforation while in a temporary shelter after the 2015 earthquake in Nepal. Paediatr Int Child Health 2018;38:69-72.
34. Yorifuji T, Sato T, Yoneda T, et al. Disease and injury trends among evacuees in a shelter located at the epicenter of the 2016 Kumamoto earthquakes, Japan. Arch Environ Occup Health 2018;73:284-291.
35. Yang X, Liu Q, Zhang R. Epidemiology of pulmonary tuberculosis in Wenchuan earthquake stricken area: population-based study. J Evid Based Med 2013;6:149-156.
36. Malla T, Malla KK, Singh SK, Shrestha S. Analysis of Post Earthquake Disease Pattern in a Camp at Gyampesal Gorkha. Kathmandu Univ Med J (KUMJ) 2016;14:249-253.
37. Pascapurnama DN, Murakami A, Chagan-Yasutan H, Hattori T, Sasaki H, Egawa S. Prevention of Tetanus Outbreak Following Natural Disaster in Indonesia: Lessons Learned from Previous Disasters 2016;238:219-227.
38. Afshar M, Raju M, Ansell D, Bleck TP. Narrative review: tetanus-a health threat after natural disasters in developing countries. Ann Intern Med 2011;154:329-335.
39. Centers for Disease Control and Prevention. Tetanus. Available from: https://www.cdc.gov/tetanus/clinicians.html#wound-management Accecced August 14, 2023.
40. Mavrouli M, Mavroulis S, Lekkas E, Tsakris A. Infectious Diseases Associated with Hydrometeorological Hazards in Europe: Disaster Risk Reduction in the Context of the Climate Crisis and the Ongoing COVID-19 Pandemic. Int J Environ Res Public Health 2022;19:10206.
41. Socolovschi C, Angelakis E, Renvoisé A, et al. Strikes, flooding, rats, and leptospirosis in Marseille, France. Int J Infect Dis 2011;15:710-715.
42. Londesman LY. Public Health Management of Disaster The Preactıce Guide. 2nd ed. New York: American Public Helath Association; 2005.
43. Neuberger A, Tenenboim S, Golos M, et al. Infectious diseases seen in a primary care clinic in Leogane, Haiti. Am J Trop Med Hyg 2012;86:11-15.
44. Ramirez M, Peek-Asa C. Epidemiology of traumatic injuries from earthquakes. Epidemiol Rev 2005;27:47-55.