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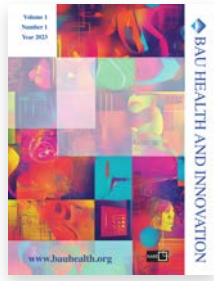

Review

Salvaged Death

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Abstract

Every year, millions of people around the world are affected by both natural and man-made disasters. Earthquakes are among the disasters that cause severe destruction and loss of life. Salvaged deaths occur as a result of crush syndrome and its associated complications. Immediate deaths that occur during an earthquake are unavoidable. However, the management of serious injuries and other issues in earthquake survivors is a matter of life and death. The primary causes of salvaged deaths include inappropriate interventions at the disaster site, limited resources, and delays in reaching earthquake victims. The post-earthquake crisis, including search and rescue operations, debris removal, and medical care for survivors pulled from the rubble, requires a systematic approach. To prevent salvaged death, effective interventions must be carried out both under the rubble and after survivors are rescued. The health professional firstly evaluates the area, makes the necessary evaluations with triage, provides medical assistance, and ensures referral to the appropriate health institution. Case management during earthquakes is a challenging process for health-care professionals. The main principles at this stage are to stop bleeding, ensure airway patency, prevent hypothermia, and initiate fluid resuscitation. Fluid resuscitation should begin immediately with an intravenous or intraosseous line before the crushed area is released. From this perspective, it is critical to begin medical treatment for earthquake victims as soon as possible, even while still trapped under the rubble. Therefore, it is essential to train and develop experienced health-care professionals who have received the necessary education.

Keywords: Crush syndrome, earthquake, salvaged death.

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Every year, millions of people around the world are affected by both natural and man-made disasters. Earthquakes, tsunamis, floods, and landslides are natural disasters, whereas hurricanes, major rail accidents, aviation crashes, terrorist attacks, and wars can be defined as man-made disasters. Looking at the regional distribution of disasters around the world, it is known that 800 million people live in these areas.[1]

An earthquake is defined as "the event of vibrations caused by sudden fractures in the earth's crust, which spread in waves and shake the environment and the surface through which they pass". Earthquakes are among the most destructive disasters in the world and Türkiye. Due to their destructive nature, earthquakes cause extensive and permanent damage as well as significant loss of property and human life.[2,3] Looking at earthquakes that have occurred around the world, on January 12, 2010, a magnitude 7.0 earthquake in Haiti resulted in 160,000 deaths; on December 26, 2004, a magnitude 9.1 earthquake in Indonesia resulted in 227,898 deaths; and on May 12, 2008, a magnitude 7.9 earthquake in Sichuan, China resulted in 87,587 deaths.[4]

Türkiye has also experienced many destructive earthquakes. Examples include the 1939 Erzincan earthquake with a

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magnitude of 7.9, which claimed 32,968 lives, and the 1999 Gölcük earthquake with a magnitude of 7.8, which claimed 17,480 lives. On February 6, 2023, two major earthquakes with magnitudes of 7.7 and 7.6 struck the Kahramanmaraş region, specifically Pazarcik and Elbistan, and are referred to as the "disaster of the century." According to data from the Ministry of the Interior as of February 8, 2024, a total of 53,637 people were reported to have lost their lives as a result of these earthquakes.[5–8]

Salvaged death refers to the sudden deterioration of the general condition and systemic clinical presentation in survivors rescued from the rubble, leading to death. Salvaged death occurs as a result of crush syndrome and subsequent complications.[9] In 1923, Japanese dermatologist Sergio Minami examined the renal histopathology of three soldiers trapped under rubble after World War I and described the pathogenesis of crush syndrome. In 1941, British physician Eric Bywaters became the first physician to formally define Crush Syndrome after examining the cases of four victims of an air raid in London during World War II.[10] After the 1988 Spitak earthquake in Armenia, which claimed the lives of approximately 25,000 people, the importance of the salvaged death came to the fore. The crush syndrome gained importance in Türkiye after the 1999 Marmara earthquake.[11,12] It is impossible to prevent the immediate deaths that occur during an earthquake. However, the management of serious injuries and other problems in earthquake victims is a matter of life and death.[13] In this review, we have attempted to summarize, using examples from the literature, the initial response to earthquake victims trapped under debris, their rescue, and the post-rescue interventions necessary to prevent salvage deaths.

Crush Syndrome

The word "crush" means "to crush, compress, or apply pressure." Crush syndrome refers to the systemic damage caused by trauma and the subsequent damage to the body. It can be defined as the development of hypercalcemia, acute renal failure, compartment syndrome, and infection due to rhabdomyolysis. The primary cause of death in earthquake victims is direct trauma, whereas the secondary cause is the complications that develop after crush syndrome.[14] It has been reported that 3–20% of earthquake deaths are due to crush syndrome, caused by the compression and crushing of people trapped under collapsed buildings. In addition, 2–15% of survivors develop crush syndrome after an earthquake, with mortality rates as high as 48%. The proportional distribution of the most commonly injured areas due to crush syndrome is as follows 9% in the upper body, 10% in the upper extremities, and 74% in the lower extremities.[1]

Rhabdomyolysis occurs as a result of muscle injury, leading to the release of intracellular components such as myoglobin and electrolytes, and the breakdown of the sarcolemmal membrane, which then enters the bloodstream. The sodium–potassium pump in the sarcoplasmic membrane maintains the balance of sodium, potassium, and calcium inside and outside the cell. However, muscle damage disrupts this balance, causing an imbalance in the flow of intracellular calcium and sodium. Sodium enters the cell, causing cell swelling and damage to the cell membrane. The breakdown of actin and myosin proteins, which are essential for muscle contraction, leads to a lack of adenosine triphosphate, which increases intracellular calcium and causes hypercalcemia. This condition causes prolonged muscle contractions and energy depletion. In addition, hypercalcemia can lead to cardiac arrest.[15–17] As a result, myocytes break down with the loss of proteins in the membrane.[18–20] As myocytes break down, creatine kinase, myoglobin, and potassium leak into the cells and enter the circulation in large amounts. The most significant damage occurs as reperfusion injury when blood flow is restored to the injured area. When the ischemic tissue is reperfused, activated neutrophils and impaired lipid metabolism damage the cell's lipid bilayer. This leads to the formation of inactive molecules in the oxygen-rich body, accelerating blood flow. Myoglobins entering the circulation can directly cause nephrotoxicity, leading to renal tubular obstruction and acute renal failure.[21,22]

Compartment syndrome occurs when the pressure within the muscle fascia rises due to muscle injury, causing the muscle to swell. This occurs when the pressure between the compartments exceeds 30 mm/Hg.[19,20] As the pressure continues, blood flow in the arteries and veins is obstructed, leading to impaired circulation. Prolonged hemorrhage and edema compression lead to tissue ischemia and necrosis. If circulation cannot be restored, irreversible peripheral nerve damage occurs. In cases of muscle breakdown, acute renal failure due to myoglobinuria and metabolic acidosis may be observed.[23–25]

After crush injury, infections can develop as a result of trauma-related wounds, fractures, and surgical procedures such as fasciotomy and amputation performed during treatment. In particular, surgical site infections can lead to delayed healing, prolonged hospital stays, and reduced quality of life for earthquake victims.[26]

Field Management to Prevent Salvaged Death

The main reasons for salvaged deaths are inappropriate interventions in the field after an earthquake, the limited available resources, and the long time it takes to reach the victims. The post-earthquake crises, search and rescue operations, debris removal, and medical interventions for victims rescued from the rubble require systematic work and cooperation. At this point, it is essential for specialized and knowledgeable health professionals to understand field management and crisis management. To ensure that health professionals can perform their duties effectively, it is crucial to ensure their safety at the disaster site and to have the necessary medical equipment and medicines readily available.[27] The health professional should first evaluate the region after the earthquake. Next, triage should be carried out, urgent evaluations for earthquake victims should be performed, medical interventions should be applied, and at the end of this process, appropriate transfers to health facilities should be carried out.[28,29]

Assessing the Region

The primary responsibility of health-care professionals is to focus on the treatment and care of earthquake victims, rather than directly participating in search and rescue efforts. To achieve this, coordination should be ensured during search and rescue operations and health professionals should avoid being in uncontrolled or restricted areas.[30]

Triage

Field triage is the process of identifying and classification of victims. Triage after an earthquake is challenging and requires experience and speed of execution. The main objective in this chaotic environment is to assess earthquake victims based on the severity of their injuries, the seriousness of their health conditions, and their medical needs.[31] During the assessment phase, some of the most commonly used triage methods in the field include the Pre-Hospital Index, Circulation, Respiration, Abdomen, Motor, and Speech, Revised Trauma Score, Simple Triage and Rapid Treatment, and the Glasgow Coma Scale. Triage should be carried out systematically and regularly for earthquake victims both under the rubble, after rescue, and in the hospital.[29,32]

Medical Approach before Rescuing Victims from the Rubble

To prevent a salvaged death after an earthquake, the first intervention should be the provision of medical care. If this is done quickly and correctly, complications such as rhabdomyolysis, compartment syndrome, acute renal failure, and cardiac arrest can be avoided. Initially, if the victim is conscious, verbal communication should be attempted. The main principles at this stage are to stop bleeding, ensure airway patency, prevent hypothermia, and initiate fluid resuscitation.[13,18,33] To prevent acute renal failure, fluid resuscitation should begin immediately with an intravenous or intraosseous line before the crushed area is released. For fluid resuscitation, adults should receive 1–1.5 L/h and children 10–20 mL/kg/h of isotonic saline solution. The risk of hyperkalemia should be considered and lactated Ringer's solution should be avoided.[34,35]

Medical Approach after the Earthquake Victim has been Rescued from the Rubble

The length of time the victim has been trapped under the rubble should be assessed and reassessed. If there is massive bleeding, it should be stopped by applying a tourniquet or pressure.[29] A cervical collar should be applied to protect the cervical vertebrae and the victim should be secured to a trauma board. If there is trauma-related pain, analgesia should be administered, measures should be taken to prevent hypothermia, airway patency should be ensured, and circulation should be assessed.[36,37]

Approach to the Earthquake Victim after Medical Treatment

Temporary treatment for crush syndrome should initially be provided in field hospitals. The victim should be transferred to well-equipped hospitals as soon as possible. Transportation may be difficult in earthquake conditions, so if there are problems with road access, air, or sea routes should be preferred.[33,38]

Discussion

Gündüz and Ersoy (2022) reported that the level of knowledge of crush syndrome among emergency medical responders showed a positive and significant difference along with their intervention experience, age, education, and work experience. In addition, they found that training on crush syndrome significantly and positively increased their knowledge level.[39] In crush syndrome, untimely and improper interventions can lead to loss of life. Diagnosing and providing treatment in the chaotic environment of an earthquake zone is extremely challenging. In such situations, the knowledge, skills, and experience of health-care professionals are crucial.[40] Onan et al.[38] (2024) reported that the mortality rate of 128 earthquake

survivors with crush syndrome was higher than that of those without. They identified a lack of early intervention, lack of blood pressure monitoring, and the need for early fluid resuscitation as the main causes of mortality. Paul et al. (2009)[41] found that the risk of acute renal failure was higher in cases of crush syndrome involving the lower extremities. He et al. (2011)[42] reported that during the 2008 Wenchuan earthquake, 8.2% of 1827 survivors developed crush syndrome, and of those with crush syndrome, 42% developed acute kidney failure.

Gök et al. (2023)[43] found that the most common cause of death within the first 5 days after the Türkiye–Syria earthquake was crush syndrome. Aydin et al. (2024)[44] reported that among 62 earthquake survivors admitted to intensive care after the Kahramanmaraş earthquakes, the duration of time they were trapped under debris ranged from 12 to 222 h, and 96.8% of them developed crush syndrome. Koyuncu et al. (2023)[45] mentioned that within the 1st week after the Kahramanmaraş earthquakes, 3184 survivors who had been trapped under rubble for 4–36 h sought medical care, and 237 of them were diagnosed with crush syndrome. Buyurgan et al. (2023)[46] reported that 18.8% of the 1110 earthquake survivors who presented to the hospital after the Kahramanmaraş earthquakes were diagnosed with crush syndrome.

Salvaged death occurs as a result of complications associated with crush syndrome following an earthquake. Studies show that crush syndrome is one of the leading causes of death. Research suggests that pre-earthquake training, together with effective post-earthquake intervention and medical management, plays a significant role in reducing the incidence of crush syndrome and its morbidity and mortality.

Conclusion

Earthquakes are among the natural disasters that cause severe destruction and loss of life. Interventions during and after rescue operations are critical to prevent salvaged deaths. Prolonged evacuation efforts, limited resources and the inability to provide timely necessary interventions contribute to the occurrence of salvaged death. For health-care professionals, case management during earthquakes is a challenging process. From this perspective, it is essential to provide immediate medical care to earthquake survivors, even if they are still trapped under the rubble. It is therefore vital to train and develop experienced health professionals who have the necessary training for such critical situations.

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