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Review

Earthquake Related Orthopedic Traumas

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ABSTRACT

Earthquakes are natural events which can cause serious injuries and deaths in the affected areas. Orthopedic injuries are also very common in these events. The orthopedic surgeon's role includes interventions such as the temporary or definitive treatment of fractures, debridement, amputation, and fasciotomy. In this review, open fractures, crush injuries, compartment syndrome, and patients with crush syndrome and fractures which develop without being under debris, which are frequently encountered by orthopedic surgeons after an earthquake, will be reviewed with case examples in light of the literature.

Keywords: Crush syndrome, compartment syndrome, crush injuries, earthquake

Introduction

Earthquakes are natural events which can cause serious injuries and deaths in the affected areas. Although branches such as emergency medicine, general surgery, nephrology, orthopedics and traumatology are among the most intensively focused on branches in earthquake regions in the early period after an earthquake, the patient density of all branches increases significantly after the acute period (1).

The role of orthopedics and traumatology in earthquake injuries is quite large. The biggest reason for this is that patients who develop cranial or solid organ pathology usually die while under the debris (2). The most common procedures performed by orthopedic surgeons include interventions such as the temporary or definitive treatment of fractures, debridement, amputation and fasciotomy.

When an orthopedic trauma is encountered, the patient should be evaluated in detail in terms of other traumas such as solid organ pathology, chest trauma and cranial trauma. In particular, patients rescued from under collapsed structures should be considered as having spinal injuries until proven otherwise, and their transport should be carried out with the assistance of cervical collars and spine boards (3). For this reason, patients must be evaluated in a multidisciplinary manner and treated based on prompt decisions.

The authors have experience working for two weeks starting from the 24th hour after an earthquake in emergency hospitals and trauma centers where patients were referred. They have played a role in both emergency and definitive treatments of earthquake-related orthopedic traumas. This article includes examples of the five main groups of patients, which have been grouped by the authors and their discussion with the literature on these examples is given.

Management of Open Fractures

Open fractures are common after earthquakes (4). Studies have shown that this rate is 22% (5). Open fractures may occur as a result of the broken ends of the soft tissue integrity, or they may occur due to external trauma. Since earthquake injuries are usually caused by external high-energy trauma, there is a high risk of contamination, and

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therefore all open fractures resulting from earthquakes should be considered contaminated.

Open fractures are orthopedic emergencies and their treatment should begin at the scene. First of all, neurovascular pathologies should be evaluated and the wound should be wrapped cleanly with a wet gauze soaked in saline. Then, if possible, the extremity should be stabilized. After this stage, the patient should be transferred to the hospital, the patient's wound should be washed in the emergency room, tetanus prophylaxis should be applied and antibiotic therapy should be started. Tetanus immunoglobulin should be added to the treatment if the injury is dirty, non-viable tissue is present, or 6 hours have passed since the injury (6). In open fractures, prophylactic antibiotics should be administered for 24-72 hours, depending on the type. The most widely used classification in open fractures is the Gustilo-Anderson classification (Table I). Since earthquake injuries are considered Type III, a triple combination of first-generation cephalosporin, aminoglycoside (3-5 mg/kg/day gentamicin), and penicillin (2 million IU IV every 4 hours or vancomycin/clindamycin) should be administered. Taking pictures of the wound is also very important in terms of documentation.

Due to the urgency, detailed imaging is not required in earthquake injuries, but it is useful to evaluate the fracture configuration, bone defect and foreign bodies with anteroposterior and lateral radiographs which can be taken quickly. Computed tomography may be useful for surgical planning in joint fractures. If the patient's vital signs are stable when the intervention in the emergency department is completed, the patient is transferred to the operating room for further orthopedic interventions.

The first procedure to be performed in the operating room is detailed debridement. Debridement should be performed systematically from the superficial to the deep. Areas of skin which do not have circulation should be removed, but border areas may be given a chance. All suspicious areas in the fascia should be removed. In muscle debridement, the decision is made according to color, consistency, contractility and bleeding capacity. Suspected muscle tissue should also be debrided (7). Tendons which do not require repair should be preserved as much as possible. At the end of the debridement, the tendons should be covered with soft tissue. Bone fragments which do not remain in contact with the periosteum should be excised. Bacterial contamination can be reduced by irrigation after debridement.

Table I. Gustilo-Anderson open-fracture classification

Type	Description
Type I	Clean wound <1 cm in diameter with simple fracture pattern and no skin crushing
Type II	A laceration >1 cm and <10 cm without significant soft tissue crushing. The wound bed may appear moderately contaminated
Type IIIa	Adequate soft tissue coverage of the fracture despite high energy trauma or extensive laceration or skin flaps
Type IIIb	Inadequate soft tissue coverage with periosteal stripping
Type IIIc	Any open fracture that is associated with a vascular injury that requires repair

Fixation should be planned after debridement. Fracture fixation is crucial for bone and soft tissue healing and the prevention of infection (8). The fixation method is decided on according to the type of fracture. Classification is best evaluated intraoperatively, as the extent of the soft tissue injury and the degree of contamination is best assessed during surgery (9).

Type I fractures can be treated as closed fractures. However, since earthquake injuries are considered contaminated, all open fractures should be considered Type III regardless of size (9). In type II and type III fractures, if the vital soft tissue remaining after debridement is large enough to close the implant, definitive fixation can be applied. Otherwise, temporary external fixation and, in appropriate cases, a vacuum-assisted wound closure device can be used. This device acts by both reducing edema and stimulating the formation of granulation tissue. Graft or flap surgery can be applied when it has been ensured that there is no infected or dead tissue in the wound in the following sessions.

One patient in our sample had a type II open distal tibia fracture. After debridement of the open fracture in the operating room, temporary fixation was made with an external fixator and preparations for definitive treatment were started (Figure 1).

Crush Extremity Injury

Crush injuries of the extremity are very common, as injuries which develop after an earthquake are usually very high-energy. Crush injuries are severe injuries. Severe extremity injury is a condition in which three of the four tissue components (bone, vessel, nerve, soft tissue) in the extremities are damaged (10). Although the approach to these injuries is very similar to the approach to open fractures, there are also differences in terms of the need for aggressive treatment.

Figure 1. A patient with type II open tibial fracture temporarily fixed with an external fixator

The Mangled Extremity Severity Score has been defined to determine whether acute amputation or extremity salvage interventions should be performed in patients with crush injuries of an extremity (11). In this scoring system, the mechanism of injury, the vascularity of the extremity, the patient's age, and the patient's hemodynamic status (systolic blood pressure) are included. According to this scoring, it is possible to decide whether to perform limb-salvage surgery or amputation. Considering the high energy of the injuries seen in earthquakes and the prolonged ischemic duration of the patients, the appropriate treatment method for the patients is usually amputation.

Another guiding scoring system for patients with crush injuries is the Limb Salvage Index scoring system (12). A more detailed evaluation can be achieved with this scoring system. Parameters such as artery, nerve, bone, skin, deep vein, and warm ischemia time are evaluated.

The treatment choice for such patients is amputation even in fully equipped trauma centers, as amputation is both therapeutic and life-saving in crush injuries which develop after earthquakes, considering the lack of monitoring and follow-up facilities, the deficiencies in supportive treatment, the need for a multidisciplinary approach and excessive patient loads. Considering that scoring systems and examinations cannot be carried out under appropriate conditions in large disasters such as earthquakes which affect many people, sometimes a decision to treat with a clinical sense may have to be taken. Studies have shown that 1.23% of earthquake-related injuries require amputation (13).

A patient in our sample was a young male patient who was freed from the debris in the 24th hour (Figure 2). The patient had no additional trauma, except for a crushed leg. The patient was conscious, but his cooperation was not complete. There was no sensation on the sole of the foot. Distal pulses were not palpable. Under the conditions at that time, the laboratory data of the patient could not be evaluated in the preoperative period. The patient underwent emergency below-knee amputation.

Compartment Syndrome

Compartment syndrome is the development of increased tissue pressure in a closed osteofascial compartment, preventing capillary blood flow, causing ischemia in muscle and nerve tissues, and the development of permanent loss of function. Neural and muscle ischemia becomes irreversible within 6-8 hours after intra-compartmental pressure increases.

Diagnosing compartment syndrome begins with suspicion. In the conscious patient, pain, numbness, tingling, especially with passive stretching, and the inability to receive distal pulses in the later stages of compartment

Figure 2. A patient with a crush injury to the leg

syndrome are observed. Obtaining distal pulses does not rule out compartment syndrome. Differential diagnoses with crush syndrome should be made in these patients. In crush syndrome, the energy of the trauma is higher and the ischemia time is longer.

Compartment syndrome should be suspected in the presence of stiff and painful extremities after the patient is freed from debris after an earthquake. Diagnostic methods via measuring the compartment pressure invasively are not usually possible in an earthquake zone under emergency conditions.

Treatment methods in the presence or suspicion of compartment syndrome vary according to timing. Fasciotomy within the first 8 hours is crucial for the prevention of permanent sequelae in patients with injury. However, it is thought that fasciotomy can be applied and be beneficial in patients admitted between 8-24 hours after trauma. It is thought that performing fasciotomy after 24 hours increases complications such as infection and does not prevent permanent sequelae (14).

One patient in our sample presented with an injury in his hand. His pain increased severely with passive stretching. A fasciotomy was performed on the patient, including the hand and forearm (Figure 3).

Unfortunately, it is not possible to prevent all problems in patients after fasciotomy. Fasciotomy is a common surgical procedure which can be performed after trauma related compartment syndrome and its complications are not uncommon. Good wound care in the fasciotomy area is essential. In cases of infection in the fasciotomy area, repeated debridements must be applied.

Despite all supportive treatments after fasciotomy, the amputation rate was seen to be 14.8% (15). Amputation should be performed in those patients who have undergone fasciotomy in the presence of established necrosis at the demarcation line despite appropriate wound care, or in cases where the metabolic picture progressively deteriorates.

Figure 3. A patient with compartment syndrome

Crush Syndrome

Crush syndrome is one of the most common injuries after an earthquake. However, crush syndrome and crush injury of the extremity are different conditions and should be separated from each other. Muscle destruction develops in the crushed extremity in crush syndrome. After the toxic metabolites formed are added to the circulation, a clinical spectrum leading to multi-organ failure, renal failure, electrolyte disorders and even death is observed. Metabolic disorders, prevention strategies and nephrological perspectives on crush syndrome will be discussed in other sections.

In disasters where the number of patients is very high, a multidisciplinary approach and close follow-up in crush syndrome are also difficult. It is known that up to 20% of patients die immediately after being pulled out of the debris (16). In patients with crush injuries, intravenous fluid should be given as soon as possible, and even if possible, before being pulled out of the debris.

Despite all treatment methods, the difficult point in making a decision in treatment is deciding whether to perform an amputation in crush injuries. One of the most difficult decisions for an orthopedist is to amputate the extremity. Orthopedic wound care, fasciotomy, and debridement may be sufficient under conditions where close monitoring can be achieved and ideal fluid-electrolyte treatment can be provided under normal conditions. However, in extraordinary disaster situations, patients may be lost because they cannot receive adequate fluid-electrolyte treatment. In such cases, amputation removes the source of toxic metabolites and becomes a life-saving intervention. One patient in our sample was a 16-year-old male patient, who was freed from the earthquake debris at the 48th hour. He was resuscitated and intubated due to the development of cardiac arrest immediately after arriving at the hospital after his first examination (Figure 4). There were no distal pulses in his extremity and the extremity was purple in color. The patient underwent an emergency transfemoral amputation. The patient was extubated on postoperative day 0 after supportive treatment after amputation and was referred for further treatment.

As seen in this example, it may be necessary to take aggressive treatment decisions in extraordinary disaster situations. Of course, it would be more appropriate to apply gradual treatment instead of making aggressive decisions in centers with adequate monitoring and multidisciplinary work opportunities. Sometimes, however, amputation is a life-saving surgical procedure.

Figure 4. A patient with crush injury to the right leg

Closed Fractures

Although injuries such as open fractures and compartment syndrome are the first to come to mind when earthquake-related orthopedic traumas are mentioned, non-crush injuries are also not uncommon. Those individuals who stand up or try to run during an earthquake may also be exposed to orthopedic traumas due to severe shaking.

The authors' observation is that hip fractures or distal radius fractures are common in elderly osteoporotic patients, while rotational ankle traumas and ankle fractures are common in younger patients. In patients with this type of fracture, the first intervention should be performed with splints in the first center, the extremity should be elevated if possible, and then, considering that definitive treatment cannot be performed in the earthquake zone, referral to a trauma center should be provided. In one example, it was seen that the surgical treatment of a 32-year-old female patient who received a trimalleolar fracture while trying to run during an earthquake was performed in the trauma center to which she was referred (Figure 5).

Ethics

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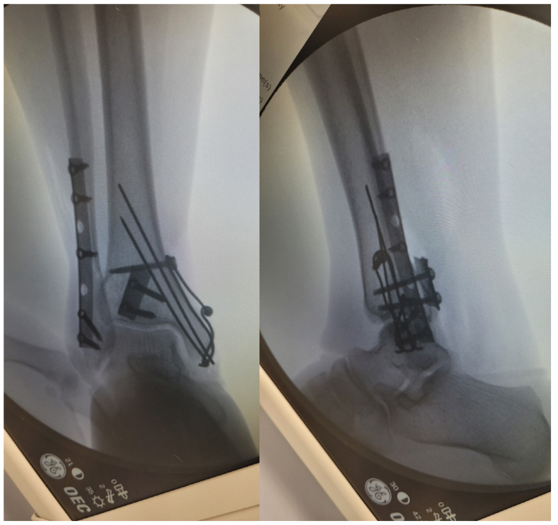

Figure 5. AP and lateral X-ray view of a trimalleolar fracture patient

References

1. Özdemir G, Karlıdağ T, Bingöl O, et al. Systematic triage and treatment of earthquake victims: Our experience in a tertiary hospital after the 2023 Kahramanmaras earthquake. Jt Dis Relat Surg 2023; 34:480-7.
2. Xu S, Shi B, Yuxian J, et al. Comparative Analysis of the Wounded in Patients and Deaths in a Hospital Following the Three Major Earthquakes in Western China. Front Public Health 2022; 10:775130.
3. Hax J, Teuben M, Halvachizadeh S, et al. Timing of Spinal Surgery in Polytrauma: The Relevance of Injury Severity, Injury Level and Associated Injuries. Global Spine J 2023; 21925682231216082.
4. 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; 117:934-41.
5. 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.
6. Halawi MJ, Morwood MP. Acute Management of Open Fractures: An Evidence-Based Review. Orthopedics 2015; 38:1025-33.
7. Artz CP, Sako Y, Scully RE. An evaluation of the surgeon's criteria for determining the viability of muscle during debridement. AMA Arch Surg 1956; 73:1031-5.
8. Worlock P, Slack R, Harvey L, Mawhinney R. The prevention of infection in open fractures: an experimental study of the effect of fracture stability. Injury 1994; 25:31-8.
9. Gustilo RB, Anderson JT. JSBS classics. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. Retrospective and prospective analyses. J Bone Joint Surg Am 2002; 84:682.
10. Gregory RT, Gould RJ, Peclet M, et al. The mangled extremity syndrome (M.E.S.): a severity grading system for multisystem injury of the extremity. J Trauma 1985; 25:1147-50.
11. Helfet DL, Howey T, Sanders R, Johansen K. Limb salvage versus amputation. Preliminary results of the Mangled Extremity Severity Score. Clin Orthop Relat Res 1990; 256:80-6.

12. Russell WL, Sailors DM, Whittle TB, Fisher DF Jr, Burns RP. Limb salvage versus traumatic amputation. A decision based on a seven-part predictive index. Ann Surg 1991; 213:473-80.

13. Bortolin M, Morelli I, Voskanyan A, Joyce NR, Ciottone GR. Earthquake-Related Orthopedic Injuries in Adult Population: A Systematic Review. Prehosp Disaster Med 2017; 32:201-8.

14. Finkelstein JA, Hunter GA, Hu RW. Lower limb compartment syndrome: course after delayed fasciotomy. J Trauma 1996; 40:342-4.

15. Moran BJ, Quintana MT, Michael Scalea T, DuBose J, Feliciano DV. Two Urgency Categories, Same Outcome: No Difference After "Therapeutic" vs. "Prophylactic" Fasciotomy. Am Surg 2021; 89:614-20.

16. Michaelson M, Reis ND. Crush injury--crush syndrome. Unfallchirurg 1988; 91:330-2.