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# Earthquake Related Injuries: Assessment of 854 Victims of the 2003 Bam Disaster Transported to Tertiary Referral Hospitals

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## Abbreviations:

AIS = Abbreviated Injury Scale  
GCS = Glasgow Coma Scale  
ICU = intensive care unit  
ISS = Injury Severity Score

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## Abstract

**Background:** In December 2003, the residents of Bam, Iran experienced an earthquake that measured 6.6 on the Richter scale and destroyed >90% of the city. After the assessment and initial treatment of injuries at national and international field hospitals, a considerable number of victims (approximately 12,000) were transferred to tertiary referral hospitals around the country.

**Objective:** This report evaluated the injuries of 854 victims transferred to 12 referral hospitals in Tehran.

**Methods:** The demographic data, injury patterns, injury severity score (ISS), diagnosis, treatment, and outcome data of 854 Bam earthquake victims were assessed.

**Results:** There were 467 (54.7%) males and 387 (45.3%) females. The mean age of the patients was 29.0 years. Transportation by aircraft was the most common method used for evacuation, which was used to evacuate 555 patients (65%). Fifty-four percent of the victims required initial medical aid at field hospitals before transportation to Tehran. There were 1,322 patients with injuries, of which, fractures of the lower extremities were the most common (331; 25%). Limb fixation was the most commonly performed primary procedure in emergency wards (389 cases, 39.9%). The mean value  $\pm$ SD for ISS was 6.7  $\pm$ 5.2. Orthopedic operations were the most frequent surgical procedures performed (195/260 operations, 75%) and the overall mortality rate was 1.6% (n = 14).

**Conclusions:** Along with the crucial importance of aid provided by national and international field hospitals in disasters, suitable triage of casualties and preparedness of tertiary referral centers in unaffected regions also play an important role in providing medical care to disaster victims. During these situations, the number of victims cannot be predicted accurately, and sufficient medical care, particularly for orthopedic problems, can be provided by referral centers.

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## Introduction

More than 500,000 earthquakes are reported each year.<sup>1</sup> Although the vast majority is too small or too remotely located to be felt, approximately 3,000 are perceptible by humans. Of those earthquakes, 7 to 11 result in a substantial number of deaths.<sup>1</sup> Disasters, such as the one that occurred in Bam following an earthquake in 2003, require services beyond the response capacity of local facilities, mobilization of care units, and patient transportation to undamaged, backup hospitals.<sup>2–5</sup>

During the last century, the Iranian plateau has been one of the world's most seismically active areas.<sup>6</sup> On 26 December 2003 at 05:26 hours (h), residents of the ancient city of Bam in southeastern Iran experienced an earthquake that lasted 10 seconds and measured 6.6 using the Richter scale. It destroyed much of the city and caused extensive damage to local buildings and

infrastructure, including hospitals and emergency response facilities. More than 40,000 people died, 30,000 were injured, and >20,000 homes were destroyed, leaving >45,000 people homeless.<sup>7</sup> Societal necessities including water, electricity, telephone communication, and healthcare services were crippled. The city's main road and only airport also were damaged.<sup>6</sup> The earthquake ruined 95 of the 96 area's healthcare centers, and two of its three hospitals.<sup>8</sup> As a result, a large number of casualties (approximately 12,000) were transferred to various hospitals throughout the country.<sup>2</sup> Approximately 2,700 cases were admitted to hospitals in Tehran, located approximately 1,000 km (620 miles) from the disaster scene. The aim of this study was to identify and describe the types and distribution of earthquake injuries, surgical procedures, and the injury severity score (ISS) of victims of this catastrophe who were transferred to tertiary referral hospitals of Tehran, the capital of Iran. By identifying these variables, medical staff of referral hospitals can be more prepared for future earthquake-related injuries.

### Methods

Upon the arrival of casualties to the Tehran airport, victims were triaged and sent via ambulance to different hospitals based on their general condition, primary diagnosis, and level of medical care needed. The majority of the patients were sent to general hospitals that had all of the basic clinical departments. Patients transferred by ambulance or private car from Bam to Tehran were hospitalized similarly in major general hospitals. The patients were distributed to different hospitals throughout the city, so 12 major general hospitals were selected by cluster sampling as the target hospitals for the current study. This cross-sectional study was performed by reviewing medical records of all patients with earthquake-related injuries, such as entrapment under rubble, falling during the earthquake, or injuries during clean-up procedures. Recorded variables consisted of demographic data, types and distribution of injuries, ISS, initial medical care provided in emergency departments, surgical procedures, number of intensive care unit (ICU) admissions, discharge status, and mortality rate. Five university, five military, and two public general hospitals were included in this study. All of these hospitals were classified as tertiary referral centers and had specialty wards (general surgery, ICU, orthopedic surgery, neurosurgery, urology).

The Abbreviated Injury Scale (AIS) and ISS were used to determine the severity of the injuries. The AIS is a simple, numerical, method used for ranking and comparing injuries based on severity. It was developed in the 1960s to aid the investigation of road traffic crashes in the United States. For the ISS, the body is divided into six separate regions: (1) head and neck; (2) face; (3) chest; (4) abdominal and pelvic contents; (5) extremities and pelvic girdle; (6) and external. It assigns each a severity value from one (minor) to six (serious to fatal). The score is calculated by squaring and summing the three highest squares on the abbreviated injury scale from different body regions (1–8 = mild; 9–15 = moderate; >15 = severe; range of 1–75).<sup>9–12</sup> In this study, the ISS was calculated from patient admission variables, and later, diagnostic data prospectively entered into the files.

Descriptive indices including frequency (percentage), mean value and their standard deviation (SD) were calculated. All statistical processing was performed using SPSS version 13.0 software for Windows (SPSS Inc, Chicago, IL).

### Results

The earthquake nearly destroyed all major healthcare facilities in Bam, and many of the healthcare personnel were seriously injured, killed, or had disappeared. This resulted in the transport of a great number of people to hospitals in unaffected areas. After the earthquake, many national and some international search-and-rescue teams were dispatched to the disaster-stricken areas, and extricated, stabilized, and evacuated victims. Although search-and-rescue teams initially stabilized and triaged the survivors, cold weather, an overwhelming number of casualties, ineffective local coordination, and more importantly, closed roads and alleys (due to collapsed buildings) hindered their efforts.<sup>8</sup> These factors decreased the effectiveness of search-and-rescue teams in the management and treatment of victims during the early hours following the earthquake. Field hospitals deployed by national military forces and international relief teams played an important role in the triage and management of casualties.<sup>14,15</sup> On the first day, Iranian military forces set up two field hospitals in the disaster-stricken area where they performed basic and advanced emergency medical interventions. Medical management, including emergency primary care and lifesaving operations, was initiated and continued through the following days.<sup>14</sup> Twelve foreign field hospitals were deployed in the disaster zone. Field hospital personnel effectively provided initial stabilization, definitive care, and triage for thousands of injured people, mainly after the emergency phase. A shortcoming encountered during the Bam disaster regarding international help was the late settlement of foreign field hospitals. None of the foreign field hospitals operating in Bam opened within the first 24 hours after the earthquake. The first foreign field hospitals arrived on 29 December (four days after the earthquake) and the last arrived on 02 January.<sup>15</sup>

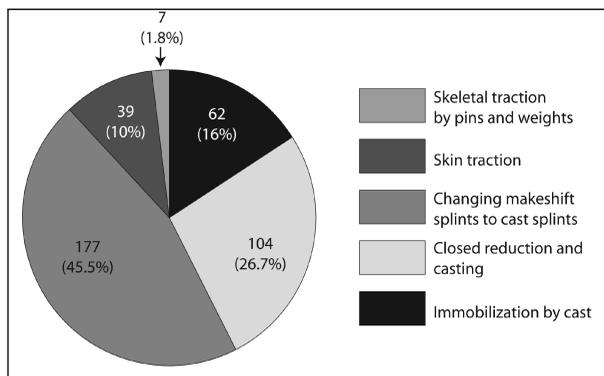
Besides the 12 foreign field hospitals, >40 countries dispatched approximately 1,600 rescue personnel through 35 urban search-and-rescue teams, 26 medical and public relief teams, and five assessment teams. These international teams played an active role in search and rescue, triage, and medical cares because local health facilities lost their function.<sup>14</sup>

A total of 854 victims with earthquake-related injuries were transferred and admitted to the 12 referral hospitals. There were 467 (54.7%) males and 387 (45.3%) females. The mean age of the patients was 29.0 years (range, 1–83 yrs). The mean value of the times between the earthquake and arrival of the patients in Tehran was 60.4 hours (range, 14 hours to 19.6 days). After being rescued from under the rubble, the majority of the evacuated victims were transferred to first-line treatment centers. Many of these centers were located in the city of Bam. Field hospitals and tents set up by health organizations, the Iranian Red Crescent, military forces, and international relief teams constituted the first places of settlement. The major initial aid rendered

Number of injuries	Patients n (%)
1	551 (64.5)
2	184 (21.5)
3	82 (9.6)
≥4	37 (4.4)
Total	854 (100)

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**Table 1**—Number of injuries per patient for casualties referred to tertiary referral centers



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**Figure 1**—Frequency of 389 limb fixation methods provided in emergency departments

(54%) in these settings consisted of intravenous fluid (IV) replacement, primary limb stabilization, and control of hemorrhage. Most casualties were transported to the airport as the second major place of settlement before air evacuation. The casualties were examined by several trained groups of medical staff at the airport terminal, and the level of medical care required was identified and categorized as red (urgent), yellow (delayed or expectant), green (minor), or black (deceased).<sup>13</sup> The criteria used for transporting victims to other areas were the extent of their injuries, triage priority, and the availability of resources. Serious patients (red) were transported to the nearest hospital by cars or ambulances. Some casualties were transported to other major cities that had sufficient resources available. Of the total patients transported to the hospital, 22.5% of victims (yellow and green) were conveyed to hospitals in Tehran.

The primary means used for the transport of the patients to Tehran hospitals were aircraft (555 cases, 65%), private cars (68 cases, 8%), ambulances (145 cases, 17%), and a combination of ambulance and aircraft for the remaining 86 (10%) victims. During transportation to Tehran, most of the victims were in stable condition and no additional care was provided during transportation except for continuing fluid or oxygen therapy. Upon arrival in Tehran, the victims were transferred to emergency departments. Upon arrival, physical examinations indicated that the mean value for the systolic and diastolic blood pressures

Type of medical treatment	Frequency	%
CPR	8	0.8
Airway management	23	2.3
Controlling of hemorrhage	76	7.8
Intravenous fluid therapy	324	33.2
Oxygen supply	80	8.2
Limb fixation	389	39.9
Spinal fixation	76	7.8
Total	974	100

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**Table 2**—Frequency of first aid managements performed in emergency departments for 854 casualties referred to tertiary referral hospitals of Tehran (CPR = cardiopulmonary resuscitation)

upon admission was 112.9 (range, 70–200 mmHg) and 71 (range, 40 to 110 mmHg), respectively. The mean values for the heart rate and ventilatory rate were 85.5 and 19.4 per minute, respectively. Three patients had a heart rate <60, and 49 had a heart rate >100 per minute. Six patients had a Glasgow Coma Scale (GCS) score of ≤8, 19 (2.2%) from 9 to 13, and the remaining 829 (97%) had a GCS score of 14–15. A total of 1,322 injuries were sustained. Five hundred fifty-one patients (64.5%) only had one injury (Table 1). Of the total, 37 (4.4%) had sustained four or more injuries.

There were 974 primary medical care procedures performed in the emergency departments. Stabilization of limbs was the most commonly performed procedure (389; 39.9%) (Table 2). Three hundred eighty-nine procedures were performed for limb fixation in emergency departments (Figure 1). Orthopedic operations were performed after stabilization and admission. Eighty (8.2%) patients received supplemental oxygen therapy. Twenty-three patients required airway advanced management, five were intubated in the emergency department and transferred to the intensive care unit, where they were mechanically ventilated. Although bandages were applied for nearly all patients with lacerations, 76 (7.8%) patients did not have any dressing or had some degrees of bleeding from their lacerations upon arrival; they were managed using pressure dressing. Sixteen patients suffered from deep lacerations. Their wounds were treated using irrigation, debridement, ligation, and suturing. None of these patients had life-threatening hemorrhaging. In addition, chest tube insertion was required in the emergency department for 43 (5%) cases (38 patients with rib fracture and associated hemopneumothorax and five patients with pneumothorax).

Among 1,322 injuries, the most common injury site was in the lower extremities (in 481 cases, 36.2%), two-thirds of which were fractures (Table 3). Fractures (745) were the most common type of injury, followed by soft tissue injuries such as skin lacerations, muscular damage, neural and vascular injuries. The ISS was calculated for 791 patients, based on the AIS score. An ISS score from 1 to 8 (considered as mild injury) was present in 490 cases (61.9%), and an ISS score from 9 to 15 (moderate injury) was calculated in 207 cases (26.2%). Ninety-four cases (11.9%) had ISS >15 indicating severe injuries. The mean ±SD ISS score was 6.7 ±5.2.

Injured Body Regions	Frequency	%
Head and neck	180	13.6
Fracture	61	34.0
Soft tissue injury	119	66.0
Face	136	10.3
Fracture	122	90.0
Soft tissue injury	14	10.0
Chest	114	8.6
Fracture	38	33.3
Soft tissue injury	76	66.7
Abdomen	106	8.0
Spinal column and cord	156	12.0
Fracture	105	67.3
Soft tissue injury	51	32.7
Upper extremity	149	11.3
Fracture	88	59.0
Soft tissue injury	61	41.0
Lower extremity	481	36.2
Fracture	331	68.9
Soft tissue injury	150	31.1

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**Table 3**—Number of body regions injured per patient for 854 casualties referred to tertiary referral hospitals

The most common medications used during hospitalization were narcotics such as meperidine and morphine sulfate (65.4%). Furthermore, 62 (2.6%) patients required blood transfusions. Prophylactic and therapeutic IV antibiotics were administered for 540 (63.2%) patients according to the site, physicians' opinions, type of injury, and degree of contamination. In some centers, the antibiotic was changed after a microbiological culture and antibiogram (antibiotic sensitivity test).

Surgical operations were performed under general anesthesia for 260 (24.1%) victims. Orthopedic surgeries were the most common 195; 75% patients. Extremity amputation was performed for 21 patients, open reduction and internal fixation (ORIF) for 105, external fixation for 37, and other operations such as debridement and fasciotomy were performed for the remaining 32 patients. Other operations included abdominal surgeries in 27 (10.3%), neurosurgeries in 17 (6.5%), maxillofacial surgeries in 15 (5.8%), and thoracic surgery in six (2.4%; Table 4).

Thirty-eight patients (22 male and 16 female) were transferred to ICUs. The mean  $\pm$ SD length of stay in the ICU was 12.1  $\pm$ 3.6 days (range: 1–72 days). The mean of the ISS scores of this group was 14.1  $\pm$ 8.16. The mortality rate of these ICU patients was 28.9% (11/38).

Of the patients, 447 (52.3%) were discharged in good condition, 21 (2.4%) with amputated extremities, and five (0.6%) were permanently disabled with traumatic paraplegia; 367 (42.9%) had various degrees of temporary disabil-

	Frequency	%
Orthopedic	192	75.0
Open reduction and internal fixation	105	53.8
External fixation	37	19.0
Extremity amputation	21	10.8
Debridement and fasciotomy	32	16.4
Neurosurgical	17	6.5
Abdominal	27	10.3
Thoracic	6	2.4
Maxillofacial	15	5.8
Total	260	100

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**Table 4**—Frequency of performed surgical operations under general anesthesia in 260 patients

ities and further follow-up and rehabilitation therapies were necessary. Three patients received unsuccessful cardiopulmonary resuscitation (CPR) upon arrival in the emergency departments. Overall, 14 patients (six males and eight females, 1.6%) died in hospital, with a mean ISS score of 12.8 (range: 4–26).

The clinical diagnoses of 63 patients were incomplete in their medical records; their ISS scores could not be determined.

## Discussion

The competence of foreign field hospitals can be assessed in three phases: (1) early emergency medical care (the first 48 hours); (2) Day 3 to Day 15; and (3) the last phase that may continue for >2 years. A foreign field hospital must be operational and on-site 24 hours after the event to be effective in the early emergency phase.<sup>16</sup> Designing an international Incident Command System (ICS) could improve the coordination between local, national, and international authorities, and result in a more rapid and effective participation of international relief teams during a disaster.

The most common type of injury encountered was long-bone fracture in the lower extremities, which is consistent with previous reports. After the Northridge earthquake in 1994, 53.6% of hospitalized patients had lower extremities injuries.<sup>17</sup> Bulut *et al* reported extremity injuries in 66.6% of patients after the 1999 Marmara earthquake.<sup>18</sup> Consequently, orthopedic operations were the most commonly performed major surgeries (195/260). This reflects

the importance of providing sufficient medical facilities, including personnel and equipment when managing future disasters.

The main medical complaints and causes of hospitalization can be different in temporary field hospitals compared to hospitals located in remote unaffected regions. Following an earthquake in 1999 in the province of Duzce, Turkey, a field hospital set up by Bar-Dayan *et al* admitted 84 patients; 90% of them due to non-traumatic illnesses. Hospitalizations were classified as internal medicine (37%), pediatrics (30%), surgery and orthopedics (18%), and obstetric/gynecology (15%).<sup>19</sup> Similarly, following an earthquake in 1999 in Adapazari, Turkey, patients with internal medicine problems such as infectious diseases, and exacerbation of chronic diseases, (myocardial infarction, diabetes, hypertension, etc.) comprised the most common cause of hospitalization in a field hospital.<sup>20</sup>

Internal medicine problems, pediatric diseases (infectious disease, neonatal care, etc.), intensive care, obstetrics/gynecologic problems, and orthopedic disorders were the next most common causes of hospitalization, respectively. Similar situations occurred for foreign field hospitals in Bam. The field hospital operated in Duzce was set up 3–4 days after the earthquakes. At this time, the majority of victims with earthquake-related injuries either had died or been evacuated to neighboring, undamaged hospitals. Secondary medical problems such as those experienced after the Duzce and Adapazari earthquakes are the predominant pattern. These problems mainly relate to environmental situations occurring after earthquakes, including a shortage of medications, sanitation, overcrowding, and stressful conditions, which put people at a high risk for communicable diseases.

The ISS scores of casualties transported to backup tertiary referral hospitals were lower than expected. It should be assumed that less seriously injured patients were transferred to hospitals in Tehran. It is likely that victims with more serious injuries and higher ISS scores were transferred to nearby hospitals in the provincial capital of Kerman or other neighboring cities. There are no reports regarding the injury severity of traumatized patients admitted to provincial hospitals. Due to a lack of data, the current ISS scores were not compared with other surveys of Bam survivors.

The majority (97%) of patients had a GCS score of 14–15, and only 4.4% had four or more injuries. These findings, along with ISS scores of <9 (low injury severity), in 61.9% of casualties, suggest that transported patients generally were in good (green) condition and more specialized procedures, particularly orthopedic interventions, had been the main need of these patients.

Several limitations should be considered when interpreting the results of this study. When a large number of patients are admitted to a hospital that was overcrowded with victims and staff, recording all pertinent information of all patients is difficult. Following the Loma Prieta earthquake, Haynes *et al* stated that the medical records in hospitals receiving excessive numbers of victims were not recorded. Some patient records were not initiated.<sup>21</sup> After receiving initial medical care on-scene, all of the patients were transported because they required more complex treatment. All of the patients transported were hospitalized before being discharged. There was not enough data regarding the initial status and treatments rendered at the field hospitals. Another limitation encountered was the method of sampling this population. Due to limited resources, only 854 of about 2,700 transferred victims were evaluated in this research.

As the world population continues to grow and urbanization increases, people are becoming more vulnerable to large earthquakes. Healthcare centers must be prepared to receive large numbers of critically ill patients in case of a disaster. These conditions can be organized through proper communications between governmental and non-governmental organizations, hospitals, institutions, and military forces. A comprehensive disaster plan is required to ensure a prompt disaster response and coordinate management (even with other countries). Detailed information about the number and severity of injuries from earthquakes is needed to compare, improve, and evaluate interventional measures and outcomes.

## Conclusions

Following an earthquake with a large number of casualties, many patients were transported to tertiary referral hospitals after triage. These patients mainly had a mild injury severity and orthopedic treatments constituted their principal demand.

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