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ORIGINAL ARTICLE

Infections after musculoskeletal injuries in earthquake survivors

Imran Hasanoglu, MD[1], Bircan Kayaaslan, MD[1], Guzelali Ozdemir, MD[2], Baris Guntekin, MD[1], Ceyhun Caglar, MD[2], Muge Ayhan, MD[1], Atahan Durgal, MD[2], Fatma Eser, MD[1], Ayse Kaya Kalem, MD[1], Rahmet Guner, MD[1]

[1]Department of Infectious Diseases and Clinical Microbiology, Ankara Bilkent City Hospital, Ankara, Türkiye
[2]Department of Orthopedics and Traumatology, Ankara Bilkent City Hospital, Ankara, Türkiye

Natural disasters of significant magnitude, such as earthquakes, result in a huge number of patients suffering from traumatic injuries, many of which are intricate and require complex medical attention. In destructive earthquakes, numerous wounds can have a huge surface area as a result of trauma-related injuries, such as open wounds, amputations, and fasciotomies.

On February 6, 2023, in the province of Kahramanmaraş, Türkiye, two major earthquakes measuring 7.8 and 7.6 on the Moment magnitude (Mw) scale occurred within a 9-h interval, resulting in significant losses. These earthquakes caused significant destruction in a total of 11 provinces. The devastating earthquake resulted in the destruction of numerous structures, including hospitals and

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Correspondence: Imran Hasanoglu, MD. Ankara Bilkent Şehir Hastanesi, Enfeksiyon Hastalıkları ve Klinik Mikrobiyoloji Bölümü, 06800 Çankaya, Ankara, Türkiye.

E-mail: imran.solak@gmail.com

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ABSTRACT

Objectives: This study aimed to investigate the infections following musculoskeletal injuries in earthquake survivors, offering a future clinical point of reference for the handling of musculoskeletal injuries resulting from earthquakes.

Patients and methods: In this single-center retrospective observational study, 225 earthquake survivors (120 females, 105 males; median: 39 years; range, 18 to 94 years) admitted between February 2023 and April 2023 were evaluated. Patients with musculoskeletal injuries and patients who had at least one month of follow-up data were included in the study. Diagnosis of healthcare-associated infections was verified by an infection control physician in accordance with the Centers for Disease Control and Prevention.

Results: Among all cultures, the most isolated pathogen was *Acinetobacter baumannii* (49.4%), followed by enterococci (28.6%). Colistin sensitivity of *A. baumannii* was 36 (94.7%). However, sensitivity rate was 5.3% for ciprofloxacin, 10.5% for piperacillin-tazobactam, and 26.4% for carbapenems, which are frequently used for skin and soft tissue infections. Among all, 76% of the microorganisms isolated from wound culture and 58% of the microorganisms isolated from deep tissue culture were found to be multidrug-resistant pathogens. During the follow-up, 12 (5.3%) patients had hospital-acquired urinary tract infections, 13 (5.7%) patients had hospital-acquired bloodstream infections, one (0.4%) patient had hospital-acquired pneumonia, and 74 (32.8%) patients had surgical site infections. Eighty (35.6%) of the patients were followed up in the intensive care unit, and the overall mortality rate was 2.7%.

Conclusion: While gram-positive microorganisms are frequently the causative microorganisms in infections after traumatic injuries, this study revealed that gram-negative microorganisms could be observed more frequently in postearthquake traumatic injuries. Most causative microorganisms are resistant to commonly prescribed antibiotics in clinical settings, which makes them more challenging to treat.

Keywords: Earthquake, infection, musculoskeletal injuries.

medical centers. Many earthquake victims were referred to hospitals in neighboring provinces, where they received initial medical interventions. Although almost 600 km away from the epicenter of the earthquake, Ankara Bilkent City Hospital was one of the most important referral centers with 4,000-bed capacity.

Open wounds can become contaminated by soil and debris, which is why there is significant concern about a high incidence of infection among earthquake survivors, as it remains a major cause of disability and mortality.[1,2] Microbiological analysis is essential to provide laboratory evidence for guiding the optimal selection of antibiotics for infection treatment and prevention and potentially reducing the risk of hospital-acquired infections (HAIs). While infections in trauma patients are now well understood, there is a lack of sufficient and diverse data regarding infections of musculoskeletal injuries in earthquake survivors. Therefore, offering a future clinical point of reference for the handling of musculoskeletal injuries resulting from earthquakes, this study aimed to evaluate the infections following post earthquake musculoskeletal injuries, distribution of causative microorganisms and their resistance profiles, treatment regimens, and follow-up results.

PATIENTS AND METHODS

In this single-center retrospective observational study, 225 earthquake survivors (120 females, 105 males; median: 39 years; range, 18 to 94 years) admitted to the departments of infectious diseases and orthopedics at the Ankara Bilkent City Hospital between February 2023 and April 2023 were evaluated. Patients with musculoskeletal injuries, ≥18 years of age, and patients who had at least one month of follow-up data were included in the study. The patients' demographic data, removal time from the rubble, injury types, and comorbid diseases were evaluated at the time of admission. They were evaluated in terms of limb loss, surgical interventions, infection development (wound infection, bone and joint infection, bloodstream infection, and urinary infection), antimicrobial treatments, intensive care unit follow-up, and mortality during the one-month follow-up.

An infectious diseases physician performed daily visits to the orthopedics inpatient clinics and determined the diagnosis of wound infection based on the observation of clinical symptoms and laboratory tests. Culture from wound, deep tissue, pus, abscess, urine, blood, and central venous catheter were obtained only when deemed necessary. Culture results considered to be contaminated were not included in the study. Infections that were not present at the time of admission and occurred 72 h after admission to the hospital were considered healthcare-associated infections. Diagnosis of healthcare-associated infections was verified by an infection control physician in accordance with the Centers for Disease Control and Prevention.

Statistical analysis

Statistical analysis was performed with IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were presented either as mean ± standard deviation for normally distributed data or numbers and frequencies.

RESULTS

Comorbidities were present in 29.8% of the patients, with diabetes mellitus being identified in 14.2% of cases and hypertension in 16.4%. It was found that 39.6% of the patients had received tetanus vaccination in the past 10 years, 84.4% had received tetanus vaccination following the earthquake, and 22.7% had received tetanus immunoglobulin. No tetanus case was observed in our center. Among the patients, 76.9% were observed to be trapped under debris for a duration ranging from 0 to 24 h. Clinical characteristics and detailed information regarding surgical procedures and invasive interventions administered to the patients are summarized in Table I.

The median length of hospital stay was 26.5 days (range, 1 to 45 days). Twenty-two (9.8%) patients received a single dose of antimicrobial prophylaxis, four (1.8%) patients received extended antimicrobial prophylaxis (lasting 24 h), and 196 (86.7%) patients received antibiotic treatment exceeding 24 h. The median duration of antibiotic treatment administered during the study was 12.5 days, ranging from 0 to 39 days. Antibiotic regimens of the patients are summarized in Table II.

Cultures were obtained from 63 (28%) patients, with 43 (68.3%) of them showing positive results for wound cultures. Additionally, deep tissue cultures were obtained from 65 (28.9%) patients, and 51 (78.5%) of them were positive for microbiological growth. The outcomes of cultures taken from wounds, tissues, blood, and urine are summarized in Table III. Among all cultures, the most isolated pathogen was *Acinetobacter baumannii (A. baumannii)* (49.4%), followed by enterococci (28.6%). The antibiotic susceptibilities of cultured microorganisms are presented in Tables IV and V.

TABLE I
Clinical characteristics of the patients

	n	%	Median	Min-Max	IQR
Age (year)			39	18-94	25-75, 28-51
Sex					
Male	105	46.7			
Presence of at least one co-morbidity	67	29.8			
Diabetes mellitus	32	14.2			
Hypertension	37	16.4			
Chronic pulmonary disease	14	6.2			
Tetanus vaccination within 10 years					
No	95	42.2			
Yes	89	39.6			
Unknown	41	18.2			
Tetanus vaccination after earthquake					
No	13	5.8			
Yes	190	84.4			
Unknown	22	9.8			
Tetanus immunoglobulin after earthquake					
No	147	65.3			
Yes	51	22.7			
Unknown	27	12.0			
Contaminated wound					
No	72	32.0			
Yes	153	68.0			
Trapped under rubble					
No	33	14.7			
Yes	192	85.3			
Removal time from the rubble (h)					
0-6	77	39.5			
6-24	73	37.4			
24-48	25	12.8			
48-72	7	3.6			
72-96	4	3.1			
96-120	3	1.5			
>120	4	2.1			
Crush					
No	30	13.3			
Yes	185	86.7			
Fracture					
Open fracture	154	68.4			
Closed fracture	17	7.6			
No fracture	54	24			
Operation					
No	16	7.1			
Yes	209	97.9			
Emergency operation					
No	133	59.1			
Yes	92	40.9			
Median number of surgeries			2	1-11	25-75, 1-3
Fasciotomy					
No	142	63.1			
Yes	83	36.9			

TABLE I
Continued

	n	%	Median	Min-Max	IQR
Amputation					
No	186	82.7			
Yes	39	17.3			
Graft					
No	184	81.8			
Yes	41	18.2			
Central venous catheter					
No	164	72.9			
Yes	61	27.1			
Urinary catheter					
No	62	27.6			
Yes	163	72.4			
Hemodialysis					
Yes	37	17,5			
No	175	82,5			
Intensive care unit (ICU) admission					
No	145	64.4			
Yes	80	35.6			
Length of stay in the first hospital			4	1-14	25-75, 2-7
Total length of stay			26.5	1-45	25-75, 11-36
Length of ICU stay			8	2-40	25-75, 4.25-18.5
Antimicrobial treatment					
Single dose prophylaxis	22	9.8			
24 h extended prophylaxis	4	1.8			
>24 h prophylaxis/treatment	196	86.7			
No	3	1.3			
Wound culture					
Growth	43	68.3			
No growth	20	31.7			
Deep issue culture					
Growth	51	78.5			
No growth	14	21.5			
Hospital acquired urinary tract infection	12	5.3			
Hospital acquired bloodstream infection	13	5.7			
Hospital acquired pneumonia	1	0.4			
Hospital acquired surgical site infection	74	32.9			
Mortality	6	2.7			

IQR: Interquartile range.

Considering the antibiotic susceptibilities of the microorganisms isolated from deep tissue and wound, colistin sensitivity of *A. baumannii* was 36 (94.7%). However, the sensitivity rate was 5.3% for ciprofloxacin, 10.5% for piperacillin-tazobactam, and 26.4% for carbapenems, which are frequently used for skin and soft tissue infections. The most isolated gram-positive microorganisms, *Enterococcus spp.*, showed an ampicillin sensitivity of 54.5%, while vancomycin resistance was detected in approximately 10%. Among all, 76% of the microorganisms isolated from wound culture and 58% of the microorganisms isolated from deep tissue culture were found to be multidrug-resistant (MDR) pathogens.

During the six-week follow-up period, 12 (5.3%) patients had hospital-acquired urinary tract infections (UTIs), 13 (5.7%) patients had hospital-acquired bloodstream infections, one (0.4%)

TABLE II
Antibiotic regimens (n=218)

	n	%	Median	Min-Max	IQR
Duration of antibiotic treatment			12.5	0-39	25-75, 5-24
Antibiotic regimens					
Cefazolin	48	22.0			
Ceftriaxone	26	11.9			
Sulbactam-ampicillin	9	4.1			
Piperacillin-tazobactam	41	18.8			
Cefepime/ceftazidime/sefoperazon-sulbaktam	8	3.7			
Meropenem	37	17.1			
Polymyxin B/colistin	14	6.5			
Treatment for antibiotic resistant Gram-positive microorganisms	77	34.2			
Regimens for antibiotic resistant Gram-positive microorganisms					
Teicoplanin	64	83.1			
Tigecycline	6	7.8			
Daptomycin	4	5.2			
Linezolid	2	2.6			
Vancomycin	1	1.3			
Treatment for antibiotic resistant Gram-negative microorganisms	62	28.4			
Regimens for antibiotic resistant Gram-negative microorganisms					
Meropenem	37	59.7			
Polymyxin B	8	12.9			
Colistin	6	9.7			
Cefepime/ceftazidime	7	11.3			
Other	4	6.5			

IQR: Interquartile range.

TABLE III
Microorganisms isolated from different samples

	Wound (n=43)		Deep tissue (n=51)		Blood (n=13)		Urine (n=15)		Total (n=77)	
Pathogen	n	%	n	%	n	%	n	%	n	%
Acinetobacter baumannii	24	55.8	20	39.2	7	53.8	5	33.3	38	49.4
Klebsiella pneumoniae	4	9.3	8	15.7	1	7.7	1	6.7	12	15.6
Stenotrophomonas spp.	3	7.0	2	3.9	1	7.7	1	6.7	6	7.8
Escherichia coli	5	11.6	4	7.8	1	7.7	4	26.7	14	18.2
Pseudomonas aeroginosa	12	20.9	12	23.5	-	-	1	6.7	20	26.0
Enterococcus spp.	7	16.3	21	41.2	-	-	-	-	22	28.6
Staphylococcus spp.	-	-	2	3.9	7	53.8	-	-	13	16.9
Enterobacter cloaca	9	20.9	9	17.6	-	-	-	-	16	20.8
Others	6	14	11	21.6	-	-	3	20.2		

patient had hospital-acquired pneumonia, and 74 (32.8%) patients had surgical site infections. Eighty (35.6%) of the patients were followed up in the intensive care unit, and the overall mortality rate was 2.7%. The cause of intensive care unit admission was not always infection, and the mortality rates were not specific to infections.

DISCUSSION

After a devastating earthquake, infection is one of the most frequent clinical issues that affect trauma patients, impeding the recovery of organ function and tissue repair and raising the disability and mortality rates of trauma patients.[3,4] The initial

TABLE IV
Antimicrobial susceptibility results of isolated gram-negative microorganisms

	Acinetobacter baumannii (n=38)		*Enterobacter cloaca* (n=16)		*Klebsiella pneumoniae* (n=12)		*Pseudomonas aeruginosa* (n=20)		*Stenotrophomonas spp.* (n=6)		*Escherichia coli* (n=14)	
Antibiotics	n	%	n	%	n	%	n	%	n	%	n	%
Ciprofloxacin	2	5.3	11	68.8	6	50	18	90			6	42.9
Imipenem	5	13.2					4	20			13	92.9
Meropenem	5	13.2			7	58.3	18	20			12	85.7
Pip-tazobactam	4	10.5	5	31.3	5	41.7	16	80			7	50.0
Amikacin	4	10.5	16	100	9	75.0	200	100			13	92.9
TMP-SMZ	10	26.3	13	81.3	8	66.7			1	16.7	8	57.1
Tigecycline	18	47.4										
Colistin	36	94.7										
Ceftazidime			5	31.3	6	50	15	75			4	28.6
Ertapenem			12	75.0	7	58.3					12	85.7
Amoxicillin clavulanic acid			0	0	4	33.3					2	14.3
Ceftriaxone			5	31.3	5	41.7					5	35.7
Levofloxacin									6	100		

TMP-SMZ: Trimethoprim/sulfamethoxazole.

TABLE V
Antimicrobial susceptibility results of isolated gram-positive microorganisms

	Staphylococci (n=13)		*Enterococci* (n=22)	
Antibiotics	n	%	n	%
Teicoplanin	13	100	20	90.9
Vancomycin	13	100	20	90.9
Ampicillin			12	54.5
Linezolid	13	100	21	95.5
Tigecycline	13	100	21	95.5
TMP-SMZ	10	76.9		
Cefoxitin	1	7.7		

TMP-SMZ: Trimethoprim/sulfamethoxazole.

wave of casualties was enormous and had to be handled under unusual circumstances, frequently with insufficient manpower, medical supplies, and antibiotics, which made it difficult to heal wounds. Furthermore, many healthcare facilities lacked reliable capabilities for conducting microbiological studies on infected wounds. The majority of hospitals were so overcrowded that medical staff were unable to deliver optimal care to those with infections. After an earthquake, the rescue operations may face delays caused by several factors, such as a high volume of injured individuals, disrupted transportation routes, communication breakdowns, adverse weather conditions, and a shortage of medical personnel.[4] Consequently, many of the injuries sustained by earthquake survivors often remained heavily contaminated and went untreated or were not promptly cleaned, leading to a high incidence of wound infections. While gram-positive microorganisms are frequently the causative microorganisms in infections after traumatic injuries, this study revealed that gram-negative microorganisms could be observed more frequently in postearthquake traumatic injuries.

A limited number of studies in the literature reported that the microbiology of wound infections following earthquakes typically differs from that of community-acquired wound infections.[5-8] Although it is a well-known fact that MDR bacteria are mostly isolated from patients with HAIs or who have antibiotic exposure, there are a few studies showing they can be the causative microorganisms of wound infections after disasters such as earthquakes and floods.[9] In our study, the most frequently isolated microorganism from trauma patients was *A. baumannii* (49.4%), followed by enterococci (28.6%). Unfortunately, the sensitivity rate of *A. baumannii* for ciprofloxacin, piperacillin-tazobactam, and carbapenems, which are frequently used antibiotics for skin and soft tissue infections, were 5.3%, 10.5%,

and 26.4%, respectively.[10,11] Moreover 76% of the microorganisms isolated from wound cultures and 58% of the microorganisms isolated from deep tissue cultures were found to be MDR pathogens, leaving physicians with limited or no options for antibiotic treatment. Kiani et al.[6] reported that *Pseudomonas spp.* (30.5%) was the most prevalent isolated microorganism in earthquake survivors, and the majority of these strains were MDR. The second most frequent microorganism was *Enterobacter spp.*, and the majority of these strains (66%) were likewise MDR. The third most frequently isolated microorganism was *Acinetobacter spp.* (15.8%), and 92% of them were MDR. After the Wenchuan earthquake in China, a study evaluated the microbiological results of 50 patients' wound infections and reported that *Escherichia coli*, *A. baumannii*, and *Staphylococcus aureus (S. aureus)* were the most isolated pathogens.[12] However, Tao et al.[13] reported different results after the same earthquake in China. The study evaluated 464 nonduplicate clinical isolates from 1,823 earthquake survivors and reported that *S. aureus* was the most commonly isolated microorganism. Subsequently, *E. coli*, *A. baumannii*, *Enterobacter cloacae*, and *Pseudomonas aeruginosa* (*P. aeruginosa*) were reported as the most frequently isolated microorganisms, respectively. Although *S. aureus* was the most frequently isolated microorganism, gram negative bacteria constituted 73% of the isolated microorganisms. *Acinetobacter baumannii* was isolated less frequently in comparison to our study.[13]

There are few studies from Türkiye regarding microbiological analysis of wound infections in earthquake survivors. This is the first study evaluating microbiological analysis of traumatic wound infections after the 2023 Kahramanmaraş earthquake. After the Marmara earthquake in 1999, Keven et al.[14] reported that *Acinetobacter spp.* and *Pseudomonas spp.* were the most isolated pathogens. There were 41 (6.4%) patients who had pulmonary infections, while 14 (2.2%) patients were diagnosed with UTIs. In our study, 5.3% of the patients had hospital-acquired UTIs, 5.7% had hospital-acquired bloodstream infections, 0.4% had hospital-acquired pneumonia, and 32.8% had surgical site infections. Kazancioglu et al.[5] reported the two main bacterial isolates from wound infections, *Acinetobacter spp.* (36%) and *P. aeruginosa* (21%), were sensitive to quinolones but resistant to carbapenems after the 1999 Marmara earthquake. In our study, the antimicrobial resistance profile was different from this study. Among *A. baumannii* isolates, the sensitivity rate was 5.3% for ciprofloxacin, 10.5% for piperacillin-tazobactam, and 26.4% for carbapenems. Oncül et al.[15] evaluated HAIs after the 1999 Marmara earthquake and reported that 18.6% of the patients experienced HAI episodes, with a mortality rate of 10%. In our study, the mortality rate (2.7%) was much lower than the rates reported in the 1999 Marmara earthquake.

There are studies reporting tetanus cases after earthquakes.[16-18] Disruption of skin integrity in those trapped under rubble after earthquakes is a significant risk factor for tetanus.[2] Although its vaccine is highly effective and accessible, tetanus still causes significant mortality and morbidity.[19] Therefore, it is crucial to evaluate patients with postearthquake injuries in terms of tetanus vaccination and to provide the appropriate intervention. In our center, upon admission, all the earthquake survivors were questioned for vaccination status. With a good medical history investigation, evaluation of vaccination status, and appropriate prophylaxis approach, no tetanus case was observed in our patients.

There are some limitations to this study. The retrospective design, lack of supporting data from other institutions in the area, and the emergency conditions due to the natural disaster are among the limitations. Furthermore, since we included only hospitalized patients, we could not evaluate the wound infection rate and risk factors.

In conclusion, after a devastating earthquake, infection is one of the most frequent clinical issues in patients with orthopedic injuries. The majority of causative microorganisms are resistant to commonly prescribed antibiotics in clinical settings, which makes it more challenging to treat. Results of our study provide a future clinical point of reference for the handling of orthopedic injuries resulting from earthquakes.

Ethics Committee Approval: The study protocol was approved by the Ankara City Hospital Clinical Research Ethics Committee (date: 22.03.2023, no: E1-23-3384). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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