

Demographic and Clinical Characteristics of Earthquake Victims Presented to the Emergency Department with and without Crush Injury upon the 2023 Kahramanmaraş (Turkey) Earthquake

Çağrı Safa Buyurgan;¹ Seyran Bozkurt Babuş;¹ Akif Yarkaç;¹ Ataman Köse;¹ Halil Oktay Usluer;¹ Cüneyt Ayrık;¹ Hüseyin Narıcı;¹ Gülhan Örekici Temel²

1. Mersin University, Faculty of Medicine, Department of Emergency Medicine, Mersin, Turkey
2. Mersin University, Faculty of Medicine, Department of Biostatistics and Medical Informatics, Mersin, Turkey

Correspondence:

Çağrı Safa Buyurgan
Mersin University Medical Faculty
Emergency Medicine Department
Mersin, Turkey 33343
E-mail: cagribuyurgan88@yahoo.com.tr

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Abbreviations:

AKI: acute kidney injury
ED: emergency department
ICD-10: International Classification of Diseases, Tenth Revision
ICU: intensive care unit
IV: intravenous
RRT: renal replacement therapy

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Abstract

Introduction: Earthquakes are sudden-onset natural disasters that are associated with substantial material damage, resulting in the collapse of built environment with a high rate of mortality, injury, and disability. Crush syndrome, which can be seen after devastating earthquakes, can lead to acute kidney injury (AKI) and patients may require amputation, fasciotomy, and dialysis. Supportive treatment has an important role in the prognosis of these patients.

Study Objective: The aim of this study was to investigate the demographic and clinical characteristics of traumatic earthquake survivors admitted to the emergency department (ED) of a hospital, which was close to the earthquake zone but not affected by the earthquake, after the February 6, 2023 Kahramanmaraş (Turkey) earthquakes.

Materials and Methods: This study was conducted by retrospectively analyzing the data of 1,110 traumatized earthquake survivors admitted to the ED of a tertiary care university hospital from February 6th through February 20th, 2023. Age; gender; time of presentation; presence of comorbid diseases; ED triage category; duration of stay under debris; presence of additional trauma; laboratory tests; presence of AKI; presence of crush injury and injury sites; supportive treatment (fluid replacement and intravenous [IV] sodium bicarbonate); need for amputation, dialysis, and fasciotomy; duration of hospitalization; and outcome of ED were evaluated.

Results: Of the 1,110 traumatic victims in this study, 55.5% were female patients. The mean age of the patients was 45.94 (SD = 16.7) years; the youngest was 18 years old and the oldest was 95 years old. Crush injury was detected in 18.8% and AKI in 3.0% of the patients. Dialysis, amputation, and fasciotomy were required in 1.6%, 2.8%, and 1.4% of the patients, respectively. In total, 29.2% of patients were hospitalized, including 2.9% admitted to the intensive care unit (ICU) and 26.3% to the relevant ward. In total, 0.3% of the patients included in the study died at ED.

Conclusion: Post-earthquake patients may present with crush injury, AKI may develop, and fasciotomy, amputation, and dialysis may be needed, so hospitals and EDs should be prepared for natural disasters such as earthquakes.

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Introduction

Earthquakes are sudden-onset natural disasters that are associated with substantial material damage, resulting in the collapse of built environment with a high rate of mortality, injury, and disability. On February 6, 2023, two consecutive earthquakes measuring 7.7 and 7.6 on the Richter scale, epicentered in Kahramanmaraş Province, southeastern Turkey, occurred at 04:17AM and 13:24PM, resulting in one of the major natural disasters of the last century. The earthquake caused immense destruction of a total of 11 provinces and 62 towns in the proximity of the epicenter. According to the available data at the time of this article, more than 50,000 people were killed and over 107,000 were injured.



Majority of fatality associated with earthquakes occur during the first hours immediately following the earthquake and are mostly due to asphyxiation, compression, and head-neck trauma.^{1,2} Injuries, mainly in the form of fractures, mostly manifest as orthopedic injuries and cause significant morbidity. Those injuries are especially prevalent in the lower extremities.³

Crush syndrome is the second most common cause of mortality upon direct impact of trauma during destructive earthquakes.⁴ Renal replacement therapy (RRT) is of vital importance in case of abnormal laboratory results indicative of acute kidney injury (AKI), fatal hyperkalemia, and severe acidosis that may develop as complications in those patients.^{5,6} Amputation, fasciotomy, and debridement may be required in cases with compartment syndrome.⁷

The present study aimed to investigate the demographic and clinical characteristics of traumatic earthquake survivors presented to the emergency department (ED) of a hospital, which was close to the earthquake zone but remained intact after the February 6th Kahramanmaraş earthquakes.

Methods

Study Design

Data from patients presented to the ED of a university hospital providing tertiary health care were retrospectively analyzed in the scope of the study.

Inclusion Criteria—Patients presented to the ED from February 6th through February 20th, 2023; diagnosed as an earthquake victim (diagnosis code X34 pursuant to International Classification of Diseases, Tenth Revision, Clinical Modification [ICD 10]); exposed to earthquake-related physical trauma; and aged 18 years or above with complete data were included.

Exclusion Criteria—Non-earthquake-related cases; earthquake-related patients who were not exposed to physical trauma; patients admitted to the ED with other medical problems; and patients with missing data were not included.

Data Analysis

Age, sex, date of presentation, comorbid diseases, ED triage category, duration of stay under debris, injury sites, specific laboratory tests (serum hemoglobin, leukocytes, platelets, urea, creatinine, sodium, potassium, calcium, phosphorus, troponin I, myoglobin, creatine kinase, and blood gas [pH, bicarbonate, base deficit] values), AKI and crush injury, treatments, ED and hospital outcomes, and length of hospital stay were recorded on the data form prepared in advance for the purposes of the study. The data were obtained by retrospectively examining the patients who applied to the ED from February 6th through February 20th, 2023, were diagnosed as earthquake victims (X34 diagnosis code according to ICD-10 diagnosis coding), and were registered in the hospital information management system NUCLEUS v9.38.50 (MONAD Software and Consultancy; Turkey) Medical Information System.

Presentation dates were captured under three categories as the “First Three Days,” “Days 4–7,” and “Days 8–14.” Triage categories at presentation were defined as Red code (immediate, life-threatening injuries), Yellow code (delayed, non-life-threatening injuries), and Green code (minimal, minor injuries). The patients’ triage categories were determined by a senior Emergency Medicine specialist. Patients who had crush injury and developed oligo-anuria (<400 mL/day) or required dialysis treatment for at

least one day were diagnosed with crush syndrome.⁸ In addition, AKI was defined as crush syndrome combined with associated nephrological conditions which might require dialysis. Patients with nephrological conditions were defined as patients who required dialysis or were characterized by one of the following parameters: oliguria (urine output \leq 400mL/day), blood urea nitrogen (BUN; >40mg/dL), urea (>85.6mg/dL), serum creatinine (>2.0mg/dL), uric acid (>8.0mg/dL), potassium (>6.0mEq/L), phosphorus (>8.0mg/dL), and calcium (<8.0mg/dL). Both RRT and its indications were determined pursuant to the recommendations of the Turkish Society of Nephrology (İstanbul, Turkey) following the 1999 Marmara earthquake in northwestern Turkey.⁹

The present study was performed upon the approval of the Clinical Research Ethics Committee, Mersin University Rectorate (Mersin, Turkey; dated March 15, 2023; No. 2023/168).

Statistical Analysis

Shapiro–Wilk test was used to test the hypothesis of normal distribution of the study data. Mean and standard deviation (SD) and median and quartiles were used as descriptive statistics for parameters that met and did not meet the normal distribution hypothesis, respectively. Categorical variables were expressed in numbers and percentages.

Student’s t-test was used to investigate presence of significant intergroup differences by mean in groups that met normal distribution hypothesis, and Mann–Whitney U test was used in the groups without normal distribution. Chi-squared test was used to investigate whether there was a correlation between categorical variables.

A P value of <.05 was considered statistically significant.

Results

A total of 5,622 patients were evaluated within the specified date range. Of those, 3,579 patients who were not related to the earthquake and 933 patients who were related to the earthquake but were not exposed to physical trauma and admitted to the ED because of medical problems were excluded from the study. There were no cases with missing data. Accordingly, the study comprised of 1,110 patients, including 55.5% female patients. The mean age of the patients was 45.94 (SD = 16.7) years. The mean age of women and men was 46.74 (SD = 17.1) and 44.93 (SD = 16.3) years, respectively (P = .075). In total, 16.1% (n = 179) of the patients included in the study aged 65 years and above. Overall, 18.8% and 3.0% of the patients were diagnosed with crush injury and AKI, respectively. Dialysis, amputation, and fasciotomy were required in 1.6%, 2.8%, and 1.4% of the patients, respectively. In total, 29.2% of patients were hospitalized, including 2.9% admitted to the intensive care unit (ICU) and 26.3% to the relevant ward. Overall, 0.3% of the patients included in the study died at ED.

The mean duration of stay under debris was 4.21 (SD = 12.6) hours and the maximum duration was 120 hours. A total of 6.5% of the patients presented with multiple traumas.

Patients mostly presented within the first three days after the earthquake. Patients with triage categories of Red and Yellow mostly presented during the first three days, whereas patients encoded Green presented on the other days (P <.0001). The rates of crush injury, AKI, and requirement for dialysis by age groups and the rates of AKI and requirement for dialysis by crush injury sites are given in Table 1.

		N (%)	P Value
Triage Category According to Days of Application			
0–3 days	Red	36 (7.4)	<.0001
	Yellow	227 (46.7)	
	Green	223 (45.9)	
4–7 days	Red	14 (3.4)	<.0001
	Yellow	138 (33.9)	
	Green	256 (62.8)	
8–14 days	Red	5 (2.3)	<.0001
	Yellow	55 (25.5)	
	Green	156 (72.2)	
Crush Injury Rate by Age Groups			
18–59		158 (18.5)	.574
60–74		39 (19.0)	
>75		12 (24.5)	
AKI Rate by Age Groups			
18–59		24 (2.8)	.816
60–74		7 (3.4)	
>75		2 (4.1)	
Dialysis Rate by Age Groups			
18–59		13 (1.5)	.887
60–74		4 (2.0)	
>75		1 (2.0)	
AKI Development Rate According to Crush Injury Site			
Upper Extremity		7 (24.1)	.108
Lower Extremity		15 (51.7)	
Head Trauma		0	
Chest Trauma		3 (10.3)	
Abdominal Trauma		4 (13.8)	
Dialysis Requirement Rate by Crush Injury Site			
Upper Extremity		2 (13.3)	.205
Lower Extremity		9 (60.0)	
Head Trauma		0	
Chest Trauma		2 (13.3)	
Abdominal Trauma		2 (13.3)	

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Table 1. Triage Categories and General Characteristics of Patients Presented upon the Kahramanmaraş Earthquake
Abbreviation: AKI, acute kidney injury.

Duration of stay under debris ($P < .0001$); injury sites ($P = .048$); serum leukocyte, urea, creatinine, sodium, calcium, troponin, myoglobin, creatine kinase, base deficit ($P < .0001$), potassium, and bicarbonate ($P = .001$) values; and duration of hospital stay ($P < .0001$) were associated with crush injury. A higher rate of patients with crush injury required amputation, fasciotomy, and dialysis ($P < .0001$); Table 2. The duration of exposure to debris ($P = .001$); serum leukocyte, urea, creatinine, sodium, potassium, phosphorus, calcium, troponin, myoglobin, creatine kinase, base deficit, and bicarbonate values ($P < .0001$); and duration of hospital stay ($P < .0001$) were associated with AKI occurrence. Similarly, the duration under debris ($P = .040$); serum leukocyte, creatine kinase ($P = .002$), urea,

creatinine, potassium, phosphorus, troponin, myoglobin, bicarbonate ($P < .0001$), sodium, calcium ($P = .001$), and base deficit ($P = .006$) values; and duration of hospital stay ($P < .0001$) were associated with the requirement for dialysis (Table 3).

The amputation rate for lower extremities was higher compared to the upper extremities in patients who required amputation (58% and 42%, respectively; $P = .421$). Similarly, the rate of fasciotomy in lower extremities was higher compared to that in the upper extremities (56.2% and 43.7%, respectively; $P = .934$). The rate of amputation was 2.9% in patients aged below 65 years of age, whereas the same rate was 2.2% in patients over 65 years of age ($P = .611$). The rate of fasciotomy was 1.6% in patients aged below 65 years and 0.6% in patients over 65 years of age ($P = .227$).

The duration under debris ($P < .0001$); serum hemoglobin, leukocyte ($P = .001$), calcium, troponin, myoglobin, creatine kinase ($P < .0001$), and base deficit ($P = .025$) values; and duration of hospital stay ($P < .0001$) were associated with amputation. Similarly, the duration under debris ($P < .0001$); serum calcium ($P = .003$), troponin ($P = .001$), myoglobin ($P = .006$), and creatine kinase ($P < .0001$) values; and duration of hospital stay ($P < .0001$) were associated with fasciotomy. Differently, serum platelet ($P = .031$), urea ($P = .009$), creatinine, potassium ($P = .049$), and sodium ($P = .007$) values were also associated with fasciotomy (Table 4).

The patients were most frequently hospitalized during the first three days (40.3%), whereas the highest discharge rate was between days eight and fourteen (83.3%), when a higher rate of Green encoded patients received medical care ($P < .0001$). One patient died during the first three days and two patients died between days four and seven at ED. In all three patients, the cause of mortality was cardiac arrest due to crush syndrome and metabolic acidosis.

There was a statistically significant, positive, and moderate linear relationship between the duration under debris and hospital stay (correlation coefficient 0.535; $P < .0001$).

Discussion

The present study provides important results as regards to AKI occurrence and amputation, fasciotomy, and dialysis in traumatic patients presented to the hospital ED upon the Kahramanmaraş earthquake.

The rate of female patients presented to the hospital was similar to the 2020 Turkey Aegean Sea–Izmir earthquake study¹⁰ and higher than the male patients. The mean age of the patients in 2020 study was 38.0 (SD = 21.0) years compared to 45.94 (SD = 16.7) years in the present study. The fact that only patients aged 18 years and above who presented to the ED were included in the present study, whereas pediatric patients were included in the 2020 study, may account for this difference.

Most post-earthquake hospital presentations occur during the first 72 hours following the disaster.^{11,12} The majority of presentations to this hospital occurred within the first three days, affirming the above hypothesis, similar to the study conducted after the 1999 Marmara earthquake in Turkey.¹³ A study on the Aegean Sea–Izmir earthquake, which measured at a lower Richter scale with a shorter duration compared to the Kahramanmaraş earthquake, reported that approximately 41.5% of the patients presented during the first three hours of the earthquake.¹⁰ For the Izmir earthquake, patients affected by the earthquake sought medical care in hospitals in the same city, and therefore, the time of presentation was earlier. The current hospital is approximately three hours by

	Crush Injury		P Value
	(+)	(-)	
n (%)	209 (18.8%)	901 (81.2%)	<.0001
Age (mean [SD]) ^a	46.0 (SD = 17.9)	45.9 (SD = 16.5)	.907
Gender (%)	54.1% Female	55.8% Female	.645
Comorbidity (n, %)	55 (27.8%)	211 (24.8%)	.385
Duration Under Debris (hours) ^b	6 [0-16]	0 [0-0]	<.0001
Injury Site (n, %)			
Upper Extremities	76 (37.8%)	27 (26.7%)	.048
Lower Extremities	79 (39.3%)	56 (55.4%)	
Head Trauma	3 (1.5%)	3 (3.0%)	
Chest Trauma	32 (15.9%)	13 (12.9%)	
Abdominal Trauma	11 (5.5%)	2 (2.0%)	
Complete Blood Count			
Hemoglobin (g/dL) ^b	12.2 [11.8-15.2]	13.1 [11.5-13.4]	.352
Leukocytes ($\times 10^3$ / μ L) ^b	12.4 [6.8-19.1]	11.1 [7.8-12.5]	<.0001
Platelets ($\times 10^3$ / μ L) ^a	258.8 (SD = 125.4)	264.8 (SD = 87.2)	.542
Biochemistry Tests			
Urea (mg/dL) ^b	16.5 [15.7-27.3]	15.0 [13.1-17.3]	<.0001
Creatinine (mg/dL) ^b	0.7 [0.6-1.1]	0.7 [0.6-0.7]	<.0001
Sodium (mEq/L) ^b	136 [134-138]	137 [135-140]	<.0001
Potassium (mEq/L) ^b	4.0 [3.7-4.7]	4.1 [3.6-4.4]	.001
Phosphorus (mg/dL) ^b	3.1 [2.4-4.1]	3.3 [3.0-3.8]	.140
Calcium (mg/dL) ^a	8.3 (SD = 0.9)	8.8 (SD = 0.8)	<.0001
Troponin I (ng/L) ^b	27.7 [7.2-120.0]	4.0 [2.2-12.2]	<.0001
Myoglobin (ng/mL) ^b	869 [272.7-3785.5]	53.6 [30.9-134.0]	<.0001
Creatine Kinase (U/L) ^b	6880 [4319.5-24331.0]	63.0 [26.0-248.5]	<.0001
Blood Gas			
pH ^b	7.3 [7.3-7.4]	7.3 [7.3-7.4]	.935
BD (g/dL) ^a	-1.5 (SD = 5.5)	0.8 (SD = 5.0)	<.0001
HCO ₃ (mmol/L) ^a	22.7 (SD = 4.3)	24.4 (SD = 5.9)	.001
Treatment			
NaHCO ₃ (n, %)	84 (42%)	44 (5.1%)	<.0001
IV Fluid (n, %)	173 (86.5%)	230 (26.4%)	<.0001
Duration of Hospital Stay (days) ^b	4.0 [2.0-10.0]	0 [0-0]	<.0001
Mortality (n, %)	2 (1.0%)	1 (0.1%)	<.0001
Amputation (n, %)	23 (11.0%)	8 (0.9%)	<.0001
Fasciotomy (n, %)	14 (6.7%)	2 (0.2%)	<.0001
Dialysis (n, %)	15 (7.2%)	3 (0.3%)	<.0001

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Table 2. Clinical Characteristics and Laboratory Data of Patients with and without Crush Injury upon Kahramanmaraş Earthquake
Abbreviations: BD, base deficit; HCO₃, bicarbonate; NaHCO₃, sodium bicarbonate; IV, intravenous.

^a Mean (standard deviation).

^b Data in square brackets indicate first and third quartile values.

land route from Hatay Province, one of the most earthquake-affected provinces and one of the provinces where patient transfers were the most common. Nevertheless, due to the damage to highways and airline runways and the failed telephone and internet connections, it took six-to-seven hours for patients to be transferred after they were rescued from under the debris. There was no direct patient transportation during the first 36 hours, except for some patients who were able to present by their own means or using a limited number of ambulances. The day after the earthquake (as of 1:00PM on February 7), a ship providing medical

services started to transport patients to the province via Iskenderun Port every 24 hours, and after the relative improvement of transportation conditions, there was marked increase in simultaneous and multiple presentations of patients. The earlier the patient is presented, the fewer complications due to earthquake-related injuries are likely expected to occur. This proves that search and rescue teams should organize their pre-disaster plans for possible mishaps in order to make patient referrals and transfers on time and reduce the duration under debris so that the national health services can be streamlined.

	Acute Kidney Injury		P Value	Dialysis		P Value
	(+)	(-)		(+)	(-)	
n (%)	33 (3.0%)	1077 (97.0%)	<.0001	18 (1.6%)	1092 (98.4%)	<.0001
Age (mean [SD]) ^a	45.2 (SD = 18.5)	45.9 (SD = 16.7)	.818	42.0 (SD = 20.8)	46.0 (SD = 16.7)	.316
Gender (%)	54.5% Male	55.8% Female	.239	50.0% Male/ Female	55.6% Female	.636
Comorbidity (n, %)	11 (34.4%)	255 (25.1%)	.234	4 (23.5%)	262 (25.4%)	.860
Duration Under Debris (hours) ^a	21.2 (SD = 23.8)	3.7 (SD = 11.8)	.001	26.1 (SD = 33.1)	3.9 (SD = 11.9)	.040
Complete Blood Count						
Hemoglobin (g/dL) ^a	13.3 (SD = 3.5)	12.8 (SD = 2.4)	.400	12.9 (SD = 4.2)	12.8 (SD = 2.4)	.924
Leukocytes ($\times 10^3/\mu\text{L}$) ^a	19.9 (SD = 8.7)	11.4 (SD = 4.7)	<.0001	19.9 (SD = 9.1)	11.7 (SD = 5.1)	.002
Platelets ($\times 10^3/\mu\text{L}$) ^a	258.7 (SD = 178.3)	263.0 (SD = 95.9)	.893	286.1 (SD = 228.3)	262.0 (SD = 95.7)	.661
Biochemistry Tests						
Urea (mg/dL) ^a	62.0 (SD = 28.7)	17.6 (SD = 8.3)	<.0001	65.1 (SD = 31.7)	18.8 (SD = 11.5)	<.0001
Creatinine (mg/dL) ^a	3.4 (SD = 2.0)	0.7 \pm (SD = 0.4)	<.0001	3.8 (SD = 2.3)	0.8 (SD = 0.6)	<.0001
Sodium (mEq/L) ^a	131.0 (SD = 5.3)	136.6 (SD = 3.4)	<.0001	131.0 (SD = 6.0)	136.4 (SD = 3.6)	.001
Potassium (mEq/L) ^a	5.4 (SD = 1.0)	4.0 (SD = 0.4)	<.0001	5.9 (SD = 1.1)	4.1 (SD = 0.5)	<.0001
Phosphorus (mg/dL) ^a	5.2 (SD = 2.1)	3.3 (SD = 1.1)	<.0001	6.2 (SD = 1.6)	3.4 (SD = 1.2)	<.0001
Calcium (mg/dL) ^a	7.6 (SD = 1.0)	8.7 (SD = 0.8)	<.0001	7.4 (SD = 1.1)	8.6 (SD = 0.8)	.001
Troponin I (ng/L) ^b	189.0 [83.5-1037.5]	6.3 [2.4-26.8]	<.0001	161.3 [79.0-1207.5]	6.8 [2.5-31.7]	<.0001
Myoglobin (ng/mL) ^b	4007 [2187.5-4007]	106.4 [38.3-611.6]	<.0001	4007 [2144.2-4007]	123 [39.9-765.0]	<.0001
Creatine Kinase (U/L) ^a	69830.3 (SD = 79358.6)	6711.3 (SD = 17857.6)	<.0001	92732.1 (SD = 96230.5)	7693.5 (SD = 19381.1)	.002
Blood Gas						
pH ^b	7.3 [7.2-7.4]	7.3 [7.3-7.4]	.010	7.3 [7.2-7.4]	7.3 [7.3-7.4]	.263
BD (g/dL) ^a	-5.7 (SD = 6.3)	0.3 (SD = 5.0)	<.0001	-6.2 (SD = 8.1)	0.1 (SD = 5.0)	.006
HCO ₃ (mmol/L) ^a	19.5 (SD = 5.0)	24.1 (SD = 5.3)	<.0001	19.2 (SD = 6.5)	23.9 (SD = 5.2)	<.0001
Treatment						
NaHCO ₃ (n, %)	26 (81.3%)	102 (9.9%)	<.0001	15 (88.2%)	113 (10.8%)	<.0001
IV Fluid (n, %)	31 (96.9%)	372 (35.8%)	<.0001	17 (100.0%)	386 (36.7%)	<.0001

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Table 3. Clinical Characteristics and Laboratory Data of Patients with Acute Kidney Injury and Dialysis upon Kahramanmaraş Earthquake (*continued*)

	Acute Kidney Injury		P Value	Dialysis		P Value
	Mean (SD)	Range		Mean (SD)	Range	
Duration of Hospital Stay (days) ^b	8.5 [3.2-15.7]	0 [0-1.0]	<.0001	10 [5.0-19.5]	0 [0-1.0]	<.0001
Mortality (n, %)	2 (6.1%)	1 (0.1%)	<.0001	3 (16.7%)	0 (0.0%)	<.0001
Dialysis (n, %)	16 (48.5%)	2 (0.2%)	<.0001			

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Table 3. (continued). Clinical Characteristics and Laboratory Data of Patients with Acute Kidney Injury and Dialysis upon Kahramanmaraş Earthquake

Abbreviations: BD, base deficit; HCO₃, bicarbonate; NaHCO₃, sodium bicarbonate; IV, intravenous.

^aMean (standard deviation).

^bData in square brackets indicate first and third quartile values.

Triage practices at ED are vital in mass disasters. The majority of patients presented to the hospital within the first three days fell under the triage category Yellow. A study by Uz, et al, which investigated the presentations after the Izmir earthquake, reported that patients encoded Yellow presented the most on the first day, with higher frequency of presentation during the first hour, and the patients encoded Yellow had the higher rate of presentation during the study.¹⁰ The fact that Green encoded patients watched for their relatives under the debris, whereas Red encoded patients had difficulty in arriving by their own means and might have been transferred only by ambulance at a later stage, may account for this result.

Head, chest, and abdominal injuries during earthquakes are generally more fatal compared to extremity injuries. Therefore, these patients who accessed health care services might be lower.³ A study on the 2015 Nepal earthquake reported the rate of lower extremity injuries as 89%.¹⁴ In the present study, the patients mostly had upper and lower extremity injuries.

Crush injuries are prevalent consequences of natural disasters, including earthquakes, and are estimated to affect 3%-20% of victims.¹⁵ Previous studies in the relevant literature suggested that children and elderly people were less likely to suffer from the pathophysiologic consequences of crush syndrome, and thus rhabdomyolysis. This was explained by the fact that younger and middle-aged people had higher rates of solid mass, and that most of the child and elderly victims who might be more prone to trauma were likely to have lost their lives during the earthquake. A Marmara earthquake study¹³ suggested the above hypothesis and reported that patients with crush injuries aged between 20 and 59 years. In the present study, the mean age of patients with crush injury was 46.0 (SD = 17.9) years.

Although it was suggested that the traumatic pressure on muscles should last at least four hours and should be continuous for crush syndrome may occur, it was reported that there were patients who were rescued within the first hour after the Kobe earthquake who developed crush syndrome.¹³ In the present study, the mean duration of stay under debris in patients with crush syndrome was six hours.

It is not only rhabdomyolysis that triggers AKI, but also the pace of rescue efforts, basic survival supplies available to patients, and meteorological conditions.¹⁶ It was reported that AKI occurred in 1.5% of all patients presented to reference hospitals during the Marmara earthquake, where the same rate was 1.9% during the Aegean-Izmir earthquake.^{10,13} In the present study, AKI rate (3.0%) was higher compared to the above two studies. The first-line treatment recommendations of the Renal Disaster Relief Force aimed to prevent AKI after the Marmara earthquake

included fluid administration started on-site and as early as possible, isotonic saline, 5.0% glucose, and bicarbonate liquid support, along with monitoring of urine output.¹⁷ Duration under debris is an important indicator as regards to occurrence of AKI due to crush injuries and is considered a factor which affects prognosis in patients.¹⁸ Most studies suggested the patients who developed AKI had longer delays in receiving supportive treatment compared to patients without AKI.¹⁰ During the Izmir earthquake, the longest duration under the rubble was 91 hours,¹⁰ whereas in the present study, it was 120 hours. It was reported that the rate of development of AKI was higher in patients with longer duration of stay under the debris in the Iran Bam earthquake, similar to the results of the present study.¹⁹ The high rate of AKI occurrence in the present study is suggestive of the fact that patients presented to the hospital had a longer duration under debris and that the patients could have received delayed medical care.

In Marmara, AKI occurred in approximately 50% of patients with crush syndrome, and approximately 50% of those patients required dialysis.¹⁷ While it was reported that 74.6% of patients with AKI in the Marmara earthquake required hemodialysis,¹³ only four (23.5%) out of 17 patients with crush injuries during the 2003 Bingöl earthquake in Turkey required dialysis.¹⁹ In the present study on the Kahramanmaraş earthquake, the same rate was 7.2%. The foregoing low rate may be explained by the fact that almost all of the patients with AKI were administered with intravenous (IV) fluid and sodium bicarbonate support pursuant to the previous recommendations. This is suggestive of the fact that the lessons taken from Turkey's long history of severe and recurrent earthquakes are beginning to clearly show their results. A mortality rate of 17% was reported in a study of post-earthquake dialysis patients,¹⁷ which is similar to the present study (16.7%).

Ischemic changes can be reversed during the first six hours by reducing compartment pressure in patients with acute compartment syndrome using fasciotomy. Amputation should be considered in patients with crush injury; in cases of all severe soft tissue damage with or without fracture; in patients with cardiac, respiratory, and renal dysfunction; and with sepsis.¹⁵ The total amputation and fasciotomy rates (3.8%) at the Aegean earthquake¹⁰ and the amputation rate (3.15%) upon the Marmara earthquake²⁰ were close to each other and similar to the results of the present study. The lower extremity amputation rate was higher compared to that of upper extremity in the present study. This may be explained by the higher rate of lower extremity injuries in these patients compared to the upper extremities and the higher incidence of nutritional disorders associated with vascular factors in the lower extremities compared to the upper extremities.

	Amputation		P Value	Fasciotomy		P Value
	(+)	(-)		(+)	(-)	
n (%)	31 (2.8%)	1079 (97.2%)	<.0001	16 (1.4%)	1094 (98.6%)	<.0001
Age (mean [SD]) ^a	43.2 (SD = 17.9)	46 (SD = 16.7)	.368	37.5 (SD = 15.4)	46.0 (SD = 16.7)	.045
Gender (%)	64.5% Female	55.2% Female	.305	62.5% Male	55.8% Female	.145
Comorbidity (n, %)	5 (18.5%)	261 (25.5%)	.408	1 (7.7%)	265 (25.6%)	.098
Duration Under Debris (hours) ^b	16 [0-40.0]	0 [0-0.2]	<.0001	12.5 [8-54]	0 [0-0.2]	<.0001
Complete Blood Count						
Hemoglobin (g/dL) ^a	10.9 (SD = 3.0)	12.9 (SD = 2.4)	.001	11.8 (SD = 3.5)	12.9 (SD = 2.4)	.277
Leukocytes (×10 ³ /µL) ^a	15.1 (SD = 5.1)	11.8 (SD = 5.4)	.001	14.3 (SD = 5.3)	11.9 (SD = 5.5)	.098
Platelets (×10 ³ /µL) ^a	277 (SD = 176.9)	262 (SD = 96.8)	.654	206.6 (SD = 73.1)	264.2 (SD = 102.4)	.031
Biochemistry Tests						
Urea (mg/dL)	16.1 [11.1-33.6] ^b	15.7 [14.6-20.4] ^b	.701	43.2 (SD = 29.8) ^a	19.7 (SD = 14.1) ^a	.009
Creatinine (mg/dL)	0.6 [0.3-1.4] ^b	0.7 [0.6-0.8] ^b	.509	2.3 (SD = 2.5) ^a	0.8 (SD = 0.7) ^a	.049
Sodium (mEq/L) ^a	136.3 (SD = 5.4)	136.2 (SD = 3.7)	.994	131.7 (SD = 5.7)	136.4 (SD = 3.6)	.007
Potassium (mEq/L) ^a	4.0 (SD = 0.8)	4.1 (SD = 0.6)	.568	4.7 (SD = 1.0)	4.1 (SD = 0.6)	.049
Phosphorus (mg/dL) ^a	3.8 (SD = 2.0)	3.5 (SD = 1.3)	.428	3.9 (SD = 1.5)	3.5 (SD = 1.3)	.294
Calcium (mg/dL) ^a	7.8 (SD = 0.9)	8.7 (SD = 0.8)	<.0001	7.3 (SD = 1.3)	8.6 (SD = 0.8)	.003
Troponin I (ng/L) ^b	43.4 [13.4-118.5]	6.8 [2.4-32.0]	<.0001	49.6 [21.5-391]	7 [2.5-33.8]	.001
Myoglobin (ng/mL)	1747.5 [582.7-4007] ^b	108 [39-762] ^b	<.0001	2283.4 (SD = 1667) ^a	834.1 (SD = 1340.6) ^a	.006
Creatine Kinase (U/L) ^b	4288.5 [1446-31063]	414.5 [26-6880]	<.0001	23589 [5028-64923.7]	504.5 [26-6880]	<.0001
Blood Gas						
pH ^a	7.3 (SD = 0.07)	7.3 (SD = 0.07)	.728	7.3 (SD = 0.08)	7.3 (SD = 0.07)	.682
BD (g/dL) ^a	-2.2 (SD = 5.3)	0.0 (SD = 5.3)	.025	0.7 (SD = 6.9)	-0.1 (SD = 5.3)	.580
HCO ₃ (mmol/L) ^a	22.2 (SD = 4.3)	23.8 (SD = 5.4)	.117	24.2 (SD = 5.8)	23.7 (SD = 5.4)	.754
Treatment						
NaHCO ₃ (n, %)	9 (32.1%)	119 (11.5%)	.004	4 (28.6%)	124 (11.8%)	.093
IV Fluid (n, %)	27 (96.4%)	376 (36.1%)	<.0001	13 (92.9%)	390 (36.9%)	<.0001
Duration of Hospital Stay (days)	5.5 [2.7-12.7] ^b	0 [0-1] ^b	<.0001	10.6 (SD = 10.8) ^a	2.3 (SD = 8.4) ^a	<.0001
Mortality (n, %)	1 (3.2%)	2 (0.2%)	<.0001	0 (0.0%)	3 (0.3%)	<.0001
Dialysis (n, %)	3 (9.7%)	15 (1.4%)	.012	5 (31.3%)	13 (1.2%)	<.0001

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Table 4. Clinical Characteristics and Laboratory Data of Patients who were Amputated and Required Fasciotomy upon Kahramanmaraş Earthquake

Abbreviations: BD, base deficit; HCO₃, bicarbonate; NaHCO₃, sodium bicarbonate, IV, intravenous.

^a Mean (standard deviation).

^b Data in square brackets indicate first and third quartile values.

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