ORIGINAL ARTICLE

Mortality Factors in Crush Syndrome

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ABSTRACT

BACKGROUND: Crush Syndrome is a major cause of morbidity and mortality following large-scale catastrophic earthquakes. Since there are no randomized controlled studies on Crush Syndrome, knowledge on this subject is limited to expert experience. The primary objective is to analyze the epidemiological and demographic characteristics, clinical outcomes, and mortality factors of earthquake victims after the Pazarcik and Elbistan earthquakes on February 6, 2023.

METHODS: This cross-sectional and observational retrospective study evaluated 610 earthquake victims who presented to our center between February 6 and April 30, 2023. Among these patients, 128 with Crush Syndrome were included in the study. Patient

Cite this article as: Onan E, Torun D, Kozanoğlu R, Miçözkadıoğlu H, Beyaz S, Özgözen L, et al. Mortality factors in crush syndrome. Ulus Travma Acil Cerrahi Derg 2024;30:174-184.

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Ulus Travma Acil Cerrahi Derg 2024;30(3):174-184 DOI: 10.14744/tjtes.2024.20532
Submitted: 25.10.2023 Revised: 25.10.2023 Accepted: 30.01.2024 Published: 05.03.2024

information was gathered from hospital records during their stay and from national registries upon referral. The primary outcome was to identify risk factors for mortality. Demographic and laboratory data were analyzed by acute kidney injury (AKI) stages; mortality-affecting factors were identified through regression analysis.

RESULTS: Of the 128 Crush Syndrome patients (100 adults, 28 children), 64 were female. The AKI rate was 32.8%. Among patients with AKI, the frequency of hemodialysis requirement was 69%, and the mortality rate was 14.2%. The overall mortality rate for patients with Crush Syndrome was 4.6%, compared to 3.9% (19/482) in earthquake victims without Crush Syndrome (p=0.705). Notably, low systolic blood pressure at admission was the only factor significantly affecting mortality in Crush Syndrome patients (Hazard Ratio [HR]: 1.088, p=0.021, 95% Confidence Interval [CI]).

CONCLUSION: Our study highlights low systolic blood pressure upon admission as a significant risk factor for increased mortality in Crush Syndrome patients. This finding may contribute to the literature by emphasizing the importance of monitoring blood pressure under rubble and administering more aggressive fluid therapy to patients with low systolic blood pressure.

Keywords: Crush Syndrome; Pazarcik; Elbistan earthquake; renal disaster.

INTRODUCTION

Crush Syndrome, also known as traumatic rhabdomyolysis, occurs when all or a part of the body is subjected to significant pressure.[1] Earthquakes are the primary causes of this syndrome, although other situations, such as building collapses, being trapped under heavy objects for extended periods, or traffic accidents, can also lead to Crush Syndrome. The most important factor influencing the development of Crush Syndrome is the severity and duration of the compression. In treating Crush Syndrome, the rapid initiation of fluid replacement is considered the gold standard to prevent acute kidney injury and related mortality. Current guidelines recommend administering isotonic saline at a rate of 1 liter per hour for adults, starting as soon as possible after rescue.[2]

The rarity of large-scale disasters leading to a high number of Crush Syndrome patients and the impossibility of conducting randomized controlled studies underscores the critical importance of sharing experiences. This is crucial for developing more effective treatment algorithms. For instance, the medical records of 600 patients who required dialysis after the earthquake in Japan in 2011 and their subsequent relocation were analyzed based on knowledge gained from previous earthquakes.[3] In an effort to contribute to the development of new algorithms for treating Crush Syndrome, our study aims to identify mortality factors in Crush Syndrome patients following the dual earthquakes in Pazarcik on February 6, 2023, at 04:17, and in Elbistan at 13:24, with magnitudes of 7.7 and 7.6 on the Richter Scale, respectively. Additionally, our study seeks to determine the morbidity and mortality rates following treatment.

MATERIALS AND METHODS

Definitions: All individuals extracted from the rubble and admitted to our hospital were classified as earthquake victims. The creatinine level upon hospital admission was considered the baseline creatinine. Acute kidney injury (AKI) levels were classified according to the Acute Kidney Injury Network (AKIN) criteria. In AKIN staging, stage 1 AKI is defined by a serum creatinine increase of 0.3 mg/dL or an increase to 1.5 times the baseline value, or a decrease in urine output (oliguria <0.5 mL/kg/hour for six hours) within 48 hours. Stage 2 AKI is defined by a two to threefold increase in the creatinine value compared to the baseline, or a urine output of <0.5 mL/kg/hour over 12 hours. Stage 3 AKI criteria include a more than threefold increase in the creatinine value or a level of >4 mg/dL, or a decrease in urine output (<0.3 mL/kg/hour for 24 hours or anuria for 12 hours). Despite being a retrospective study, patient adherence to the current protocol was closely monitored from initial admission to discharge, with all findings recorded.

Patients with serum creatine kinase (CK) >1000 U/L and oliguria (less than 500 cc urine per day), exhibiting at least one of the following parameters, were diagnosed with Crush Syndrome: serum blood urine nitrogen (BUN) >40 mg/dL, serum creatinine >2.0 mg/dL, serum uric acid >8 mg/dL, serum potassium >6 mEq/L, serum phosphorus >8 mg/dL, or serum calcium <8 mg/dL.[4]

Patients and Treatment: Following the earthquake, the Emergency Command System was activated, and trauma teams were formed. All individuals rescued from the rubble and admitted to our hospital were treated as earthquake victims. The adult and pediatric nephrology clinics implemented the Standard Crush Syndrome Emergency Nephrology Protocol (CSENP). According to the CSENP, if the earthquake victim had not received fluid therapy under the rubble, an initial administration of 1000 cc 0.9% Sodium chloride (NaCl) per hour was given upon arrival at the emergency room. This was followed by a maintenance fluid therapy of 500 cc 0.9% NaCl per hour until reaching a total of 3000 cc. After administering 3000 cc, urine output was closely monitored. If urine output was present, the infusion of 100 cc of 0.9% NaCl per hour continued. In the absence of urine output, the rate was reduced to 50 cc of 0.9% NaCl per hour. Urine output was regularly monitored, and a catheter was inserted when necessary. For pediatric patients, 0.9% NaCl was initiated at a rate of 15-20 mL/kg/hour, aiming for a urine output of approximately 3-4 mL/kg/hour.

If the patient presented with anuria upon admission, urine output of less than 50 cc/hr, elevated creatinine, brown urine color, potassium level greater than 5.5 mEq/L, pH less than 7.20, HCO3 less than 15 meq/L, and lactate less than 2 mmol/L, the team was instructed to urgently consult the Nephrology clinic. Initial hospitalization assessments included blood glucose, serum levels of sodium, potassium, calcium, phos-

phorus, BUN, creatinine, uric acid, CK, albumin, alanine aminotransferase (ALT), aspartate aminotransferase (AST), total and direct bilirubin, International Normalized Ratio (INR), urinalysis, C-Reactive Protein (CRP), venous blood gas, electrocardiography (ECG), and chest X-ray.

Upon arrival at the emergency department, all patients were triaged and evaluated according to the Advanced Trauma Life Support (ATLS) guidelines, version 10. Tetanus prophylaxis was administered to all patients, with Tetanus Immunoglobulin given to those with contaminated wounds. Prior to hospitalization, open wounds and fractures were debrided by irrigating with physiological saline solution; primary suturing was performed, and antibiotic therapy (Cefazolin 1 g, intravenously [IV]) was administered. All fractures were immobilized with a splint. Based on the results, patients were referred to the appropriate departments for hospitalization in either the general ward or the intensive care unit. Patients requiring emergent surgical interventions, such as fasciotomy or amputation, were immediately taken to the operating room. The Mangled Extremity Severity Score (MESS) was utilized to guide decisions regarding amputation in cases of crushed extremities. A joint decision-making process was undertaken among the departments of plastic surgery, orthopedics, and pediatric nephrology, particularly regarding the necessity and extent of amputation for crushed extremities in children. Patients referred to external centers for reconstructive surgery and physical rehabilitation therapy were contacted by phone, and information was obtained through national medical records.

The study was designed retrospectively. The Institutional Review Board of Baskent University Medical and Health Sciences waived the requirement for informed consent, as this study involved a retrospective review of existing data. The Baskent University Medical and Health Sciences Research Board approved this study (Project Number: KA23/168) and it was supported by the Baskent University Research Fund. This study adhered to the ethical principles outlined in the Declaration of Helsinki. The authors declare no conflicts of interest.

Blood Pressure Measurement

Blood pressure was measured using five calibrated Erka Switch 2.0 aneroid manual sphygmomanometers upon the patients' admission to the emergency department. The obtained blood pressure values were recorded in the medical records. Pediatric patients were evaluated according to their percentile ranges.

Statistical Evaluation

For statistical evaluation, the Statistical Package for the Social Sciences (SPSS) 18.0 for Windows was utilized. Descriptive statistics such as minimum and maximum values, mean, and standard deviation were calculated for quantitative data; numbers and percentages were used for qualitative data. In comparing the groups, the Chi-square and Fisher's Exact tests were applied to categorical variables; the One-Way Analysis of Variance (ANOVA) was utilized for continuous variables with a normal distribution when comparing more than two

Table 1. Demographic data of patients with Crush Syndrome

Variables	Number of Patients (Total, n=128)
Age (years, min-max)	35.9±21.91 (1-89)
Gender Distribution (M/F, n/%)	64/64 (50%/50%)
Average Time Under Rubble (hours, min-max)	29.13±27.96 (1-120)
Presence of Venous Line on Admission	
Yes (n/%)	119 (93%)
No (n/%)	9 (7%)
Comorbidities	34/85 (28.6%/71.4%)
Hypertension	16 (13.4%)
Diabetes Mellitus	8 (6.7%)
Coronary Artery Disease	8 (6.4%)
Chronic Kidney Disease	16 (12.5%)
Other	11 (9.2%)
Extremity Trauma	109 (86.5%)
Abdominal Trauma	9 (7%)
Thoracic Trauma	19 (85%)
Erythrocyte Transfusion (n)	34 (163 units in total)
Albumin Infusion (n)	1
Mannitol Infusion (n)	18 (6,450 cc in total)

Table 2. Macroscopic urine and laboratory findings of Crush Syndrome

Variables	%/Mean±SD/Median
Urine Color on Admission	
Yellow (n/%)	101 (88.6%)
Brown (n/%)	13 (10.2%)
CRP (mg/dL)	94.21±64.21
CK (U/L)	Min: 1425 - Max: 203,995, Median:16,650*
BUN (mg/dL)	34.13±29.12
Creatinine (mg/dL)	1.59±1.55
Sodium (mmol/L)	135.56±5.92
Potassium (mmol/L)	4.67±1.07
Calcium (mg/dL)	8±0.99
Phosphorus (mg/dL)	3.9±1.76
Albumin (g/L)	29.1±5.42
Hgb (g/dL)	12.6±3.6
Leukocyte (x10^9/L)	15.61±6.05
Neutrophils (x10^9/L)	78.08±10.45
Lymphocytes (x10^9/L)	13,24±11,07
Platelets (x10^9/L)	236.71±84.37
Uric Acid (mg/dL)	5.73±3.62
LDH (U/L)	Min: 151 – Max: 7.443, Median: 813*
AST (U/L)	Min: 3 – Max: 6.023, Median: 241*
ALT (U/L)	Min: 6 – Max: 5.206, Median: 116*
HCO3 (mmol/L)	21.12±4.98

Abbreviations: ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase; BUN: Blood Urea Nitrogen; CK: Creatine Kinase; CRP: C-Reactive Protein; HCO3: Bicarbonate; Hgb: Hemoglobin; LDH: Lactate Dehydrogenase; N/A: Not Applicable; SD: Standard Deviation. *The median value is indicated when the standard deviation exceeds the mean value.

groups; the Kruskal-Wallis test was employed for variables without normal distribution. The Bonferroni test was conducted for post hoc comparisons. Logistic regression analysis was performed to assess the effect of independent variables on the dependent variable. A significance level of $p<0.05$ was set for the evaluations.

RESULTS

The total number of earthquake victims admitted to our hospital was 610 (287 males, 323 females). Of these, 111 were under 18 years of age (mean age: 8.64 years, min/max: 3 months/17 years), and 499 were 18 years or older (mean age: 48.8 years, min/max: 18 years/89 years). Four hundred and one patients were hospitalized, while 209 were treated as outpatients. Geographically, 543 patients were from Hatay, 19 from Kahramanmaras, 18 from Gaziantep, and 30 from other provinces.

Among the 610 patients, 128 (100 adults, 28 children) were diagnosed with Crush Syndrome, with 64 being male (min/max: 1 year/89 years). Table 1 displays the demographic data of patients with Crush Syndrome. Table 2 outlines the urine findings, vital signs, and laboratory values at first admission for patients with Crush Syndrome.

Table 3 compares the laboratory findings of patients without AKI and those with Crush Syndrome and stages 1, 2, and 3 AKI, including post hoc comparisons. Twenty-nine of the 42 patients who developed AKI required hemodialysis (HD). For HD access, the internal jugular vein was the preferred route for intravenous access in 96.6% of the patients, while the femoral vein was chosen in 3.4%. No severe complications occurred during any HD session.

In the non-survivor group, levels of CK, BUN, creatinine, potassium, AST, ALT, and the number of hemodialysis sessions were statistically higher, while serum levels of calcium and bicarbonate, platelets, and systolic blood pressure were statistically lower compared to the survivor group (Table 4). Regression analysis indicated that lower systolic blood pressure at the time of admission significantly increased mortality in patients with Crush Syndrome (p=0.021, Hazard Ratio [HR]: 1.088, 95% Confidence Interval [CI]) (Table 5).

Table 3. Comparison of laboratory values upon admission in patients with Crush Syndrome by AKI stage

Variables	Crush Syndrome without AKI (n=86)	Stage 1 AKI (n=11)	Stage 2 AKI (n=15)	Stage 3 AKI (n=16)	Groups	P Value: Crush Syndrome without AKI	P Value: Stage 1 AKI	P Value: Stage 2 AKI	P Value: Stage 3 AKI
The Average Hour Under the Rubble (hour)	27.64±28.42	24.25±31.96	44.6±32.81	22.55±16.35	CS without AKI	*	*	*	0.497
					Stage 1 AKI				
					Stage 2 AKI				
					Stage 3 AKI				
Age (years)	34.60±22.27	43.50±25.71	40.73±20.28	32.81±18.89	CS without AKI	*	*	*	0.359
					Stage 1 AKI				
					Stage 2 AKI				
					Stage 3 AKI				
Gender (M/F)	43/43	6/5	8/7	7/9	CS without AKI	*	*	*	0.405
					Stage 1 AKI				
					Stage 2 AKI				
					Stage 3 AKI				
					Stage 1 AKI				
					Stage 2 AKI				
					Stage 3 AKI				
CRP	76.73±57.77	112.79±68.63	130.46±62.61	135.37±63.1	CS without AKI	*	0.544	0.012	0.005
Ref. range (< 2.0 mg/L)					Stage 1 AKI	0.544	*	1.000	1.000
					Stage 2 AKI	0.012	1.000	*	1.000
					Stage 3 AKI	0.005	1.000	1.000	*
CK Ref. range (30-200 U/L)	7392.00	8415.00	59519.00	67450.50	CS without AKI	*	1.000	0.001	0.001
					Stage 1 AKI	1.000	*	0.001	0.001
					Stage 2 AKI	0.001	0.001	*	1.000
					Stage 3 AKI	0.001	0.001	1.000	*
BUN Ref. range (8-23 mg/dL)	17.44	48.21	50.28	64.27	CS without AKI	*	0.001	0.001	0.001
					Stage 1 AKI	0.001	*	1.000	1.000
					Stage 2 AKI	0.001	1.000	*	1.000
					Stage 3 AKI	0.001	1.000	1.000	*
Creatinine Ref. range (0.7-1.3 mg/dL)	0.65	1.68	2.65	4.21	CS without AKI	*	0.001	0.001	0.001
					Stage 1 AKI	0.001	*	0.001	0.001
					Stage 2 AKI	0.001	0.001	*	0.001
					Stage 3 AKI	0.001	0.001	0.001	*
Sodium Ref. range (136–145 mmol/L)	136.53±4.42	136.5±8.34	134±6.97	131.44±8.2	CS without AKI	*	1.000	0.702	0.009
					Stage 1 AKI	1.000	*	1.000	0.179
					Stage 2 AKI	0.702	1.000	*	1.000
					Stage 3 AKI	0.009	0.179	1.000	*
Calcium Ref. range (8.8-10 mg/dL)	7.7±0.81	8.49±0.58	7.31±0.59	6.98±1.3	CS without AKI	*	1.000	0.001	0.001
					Stage 1 AKI	1.000	*	0.010	0.001
					Stage 2 AKI	0.001	0.010	*	1.000
					Stage 3 AKI	0.001	0.001	1.000	*
Phosphorus Ref. range (2.3-4.7 mg/dL)	3.17±1.15	4.16±1.62	4.93±1.89	5.64±2.12	CS without AKI	*	0.422	0.001	0.001
					Stage 1 AKI	0.422	*	1.000	0.147
					Stage 2 AKI	0.001	1.000	*	1.000
					Stage 3 AKI	0.001	0.147	1.000	*

Albumin									
Ref. range									
(33-46 g/L)	31.76±5.55	29.56±2.26	25.38±3.98	26.23±3.54	CS without AKI	*	1.000	0.001	0.034
					Stage 1 AKI	1.000	*	0.595	1.000
					Stage 2 AKI	0.001	0.595	*	1.000
					Stage 3 AKI	0.034	1.000	1.000	*
Hgb									
Ref. range	12.36±3.03	12.54±3.09	14.48±3.36	12.12±2.5	CS without AKI	*	1.000	0.081	1.000
(13.5-18 g/dL)					Stage 1 AKI	1.000	*	0.703	1.000
					Stage 2 AKI	0.081	0.703	*	0.188
					Stage 3 AKI	1.000	1.000	0.188	*
Leukocyte									
Ref. range	14.38±5.3	16.72±6.46	19.16±4.98	18.24±8.34	CS without AKI	*	1.000	0.032	0.100
(4.5-11 x10^9/L)					Stage 1 AKI	1.000	*	1.000	1.000
					Stage 2 AKI	0.032	1.000	*	1.000
					Stage 3 AKI	0.100	1.000	1.000	*
Neutrophils									
Ref. range									
(2-7.8 x10^9/L)	76.17±11.59	79.96±8.15	84.4±5.16	81.03±5.14	CS without AKI	*	1.000	0.028	0.493
					Stage 1 AKI	1.000	*	1.000	1.000
					Stage 2 AKI	0.028	1.000	*	1.000
					Stage 3 AKI	0.493	1.000	1.000	*
Lymphocytes									
Ref. range	11.89	10.02	5.61	9.32	CS without AKI	*	1.000	0.036	0.363
(0.9-5.06 x10^9/L)					Stage 1 AKI	1.000	*	1.000	1.000
					Stage 2 AKI	0.036	1.000	*	1.000
					Stage 3 AKI	0.363	1.000	1.000	*
Platelets									
Ref. range	245.31±88.4	229.98±49.07	230.37±65.25	201.72±91.67	CS without AKI	*	1.000	1.000	0.359
(150-400 x10^9/L)					Stage 1 AKI	1.000	*	1.000	1.000
					Stage 2 AKI	1.000	1.000	*	1.000
					Stage 3 AKI	0.359	1.000	1.000	*
Uric Acid									
Ref. range	4.18±2.26	7.69±3.7	8.17±3.83	9.11±4.36	CS without AKI	*	0.015	0.000	0.000
(3.7-7.7 mg/dL)					Stage 1 AKI	0.015	*	1.000	1.000
					Stage 2 AKI	0.001	1.000	*	1.000
					Stage 3 AKI	0.001	1.000	1.000	*
LDH									
Ref. range									
(120-246 U/L)	569.00	710.00	1614.50	2153.50	CS without AKI	*	1.000	0.013	0.018
					Stage 1 AKI	1.000	*	0.219	0.214
					Stage 2 AKI	0.013	0.219	*	1.000
					Stage 3 AKI	0.018	0.214	1.000	*
AST									
Ref. range									
(0-45 U/L)	137.00	268.50	533.00	1166.50	CS without AKI	*	1.000	0.006	0.001
					Stage 1 AKI	1.000	*	0.185	0.001
					Stage 2 AKI	0.006	0.185	*	0.009
					Stage 3 AKI	0.001	0.001	0.009	*
ALT									
Ref. range									
(0-45 U/L)	79.00	145.50	307.00	541.00	CS without AKI	*	1.000	0.285	0.001
					Stage 1 AKI	1.000	*	1.000	0.005
					Stage 2 AKI	0.285	1.000	*	0.118
					Stage 3 AKI	0.001	0.005	0.118	*
HCO3									
Ref. range									
(21-26 mmol/L)	23.59±3.62	21.17±5.23	19.71±3.53	17.79±7.75	CS without AKI	*	0.785	0.023	0.001
					Stage 1 AKI	0.785	*	1.000	0.456
					Stage 2 AKI	0.023	1.000	*	1.000
					Stage 3 AKI	0.001	0.456	1.000	*

Abbreviations: AKI: Acute Kidney Injury; ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase; BUN: Blood Urea Nitrogen; CK: Creatine Kinase; CRP: C-Reactive Protein; CS: Crush Syndrome; HCO3: Bicarbonate; Hgb: Hemoglobin; LDH: Lactate Dehydrogenase; Ref. Range: Reference Range.

Table 4. Comparison of non-survivors and survivors among patients with Crush Syndrome

Variables	Non-Survivors (n=6)	Survivors (n=122)	P
Age	51.50±21.70	35.42±21.65	0.078
Gender M/F	5 (83.3%)/1 (16.7%)	57 (47.5%)/63 (52.5%)	0.112
The Average Time Under the Rubble (hour)	33.67±18.34	29.19±28.56	0.790
Peripheral Venous Line on Admission	5(83.3%)	112(93.3%)	0.365
CRP (mg/dL)	143.92±102.77	92.3±60.94	0.275
CK (U/L)	58616	15452	0.040
BUN (mg/dL)	46.77	23.53	0.021
Creatinine (mg/dL)	3.63	0.83	0.003
Sodium (mmol/L)	134.33±7.5	135.61±5.89	0.610
Potassium (mmol/L)	6.08±1.55	4.6±1.01	0.001
Calcium (mg/dL)	7.06±0.73	8.04±0.99	0.031
Phosphorus (mg/dL)	5.2±1.04	3.81±1.76	0.179
Albumin (g/L)	25.4±6.8	29.33±5.33	0.227
Hgb (g/dL)	10.54±2.64	12.71±3.07	0.092
Leukocyte (x10^9/L)	16.21±8.63	15.55±6	0.813
Neutrophils (x10^9/L)	81.29±7.79	77.88±10.6	0.439
Lymphocytes (x10^9/L)	9.25	10.57	0.673
Platelets (x10^9/L)	168.3±78.49	239.84±83.7	0.043
Uric Acid (mg/dL)	6.57±2.14	5.67±3.65	0.674
LDH (U/L)	908.5	851	0.852
AST (U/L)	973	217	0.006
ALT (U/L)	405	114	0.015
HCO3 (mmol/L)	16.03±8.2	22.42±4.58	0.002
Systolic Blood Pressure (SBP) (mmHg)	86.67±16.33	110.88±18.72	0.002
DBP (mmHg)	56.67±10.33	67.68±13.44	0.051
Pulse (beats/min)	96.83±22.42	103.75±20.75	0.429
Respiration Rate*			
(per min)	20	20	0.059
Fasciotomy	2 (33.3%)	22(18.3%)	0.321
Amputation	1	10	0.352
Culture Positivity on Pus or Tissue	0	13	0.513
Bacteriemia			
in Other Cultures	2 (40%)	31 (26.5%)	0.611
AKI Stage			
Stage 1	0 (0%)	9 (25.7%)	0.423
Stage 2	2 (40%)	13 (37.1%)	
Stage 3	3 (60%)	13 (37.1%)	
Hemodialysis			
(number of patients)	4	25	0.028

*median. Abbreviations: AKI: Acute Kidney Injury; ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase; BUN: Blood Urea Nitrogen; CK: Creatine Kinase; CRP: C-Reactive Protein; DBP: Diastolic Blood Pressure; HCO3: Bicarbonate; Hgb: Hemoglobin; LDH: Lactate Dehydrogenase; SBP: Systolic Blood Pressure.

Table 5. Multiple regression analysis of mortality in Crush Syndrome

Variables	B	p	Exp (B)	95% CI for EXP (B)	
				Lower	Upper
Systolic BP on Admission (mmHg)	0.084	0.021	1.088	1.013	1.168
Creatinine on Admission (mg/dL)	-0.026	0.952	0.974	0.420	2.258
Potassium on Admission (mmol/L)	-0.672	0.348	0.511	0.126	2.077
Calcium on Admission (mg/dL)	1.317	0.142	3.734	0.644	21.663
AST on Admission (U/L)	0.002	0.329	1.002	0.998	1.006
HCO3 on Admission (mmol/L)	0.121	0.301	1.128	0.897	1.419

Abbreviations: AST: Aspartate Aminotransferase; BP: Blood Pressure; HCO3: Bicarbonate.

Serum CK levels measured at the first admission were significantly higher in patients who underwent fasciotomy compared to those who underwent amputation (57809.1±6039.37 U/L vs. 25754.27±18047.68 U/L, p=0.021). No significant difference was found in other parameters (for details, see Supplementary Table 1). Nine patients received hyperbaric oxygen therapy, of whom one could not survive due to septicemia (for details, see Supplementary Table 2). Six of the Crush Syndrome patients who developed AKI at different stages succumbed to various causes, such as heart failure, hyperkalemia, hypovolemic shock, disseminated intravascular coagulation (DIC), and septic shock (for details, see Supplementary Table 3).

DISCUSSION

The incidence of Crush Syndrome is reported to be 2-5% among earthquake victims and 30-50% among patients with post-traumatic rhabdomyolysis.[5] In our study, the incidence of Crush Syndrome was found to be 20.9% among all earthquake victims. Trauma-related deaths tend to be proportionally higher in earthquakes occurring during the daytime compared to deaths due to Crush Syndrome. Conversely, traumas due to crushing and Crush Syndrome are proportionally more common in earthquakes that occur at night, as people are mostly in sleeping positions. The timing (04:17 a.m.) and the extensive geography affected by the Kahramanmaras-Pazarcik earthquake, which resulted in over 50,000 deaths, may explain the higher rate of Crush Syndrome observed in our study.

The leading cause of mortality following Crush Syndrome is known to be acute kidney injury resulting from rhabdomyolysis. Current protocols advocate for the initiation of fluid replacement therapy while earthquake victims are still trapped under the rubble. In our study, the rate of intravenous fluid treatment in patients with Crush Syndrome at the time of admission was high (93%), owing to the lessons learned from the 1999 Marmara Earthquake and the prompt organization of the Renal Disaster Group by the Turkish Society of Nephrology.[6]

Biochemical abnormalities characteristic of rhabdomyolysis-related AKI include hyperkalemia, hyperphosphatemia, hypocalcemia (although hypercalcemia may be observed during recovery), elevated CK, and low fractional sodium excretion, which can pose life-threatening risks. AKI can range from mild to severe, with some cases necessitating dialysis. Our study included 11 patients with AKIN stage 1, 15 with stage 2, and 16 with stage 3. At the first admission, levels of CK, BUN, creatinine, potassium (K), AST, and ALT were statistically significantly higher, while levels of calcium, platelets, bicarbonate, and systolic blood pressure were statistically significantly lower in patients who did not survive compared to those with Crush Syndrome who did. However, regression analysis revealed no significant differences between these groups. One potential explanation is that all patients suffered from Crush Syndrome, and the number of non-survivors was relatively small.

Although hypokalemia may occur in isolated cases of Crush Syndrome, hyperkalemia represents a life-threatening condition in these patients.[6] Hyperkalemia can arise even in the absence of AKI, as injured muscle tissues may release large amounts of potassium. Upon their first admission to our hospital, potassium levels were ≥ 5.5 mmol/L in 23 patients, while 14 patients had potassium levels ranging from 2.9 to 3.5 mmol/L. Serum potassium levels did not rise in patients with Crush Syndrome who did not develop AKI or those with stage 1 AKI. However, the average potassium level in patients

with stage 2 AKI was 5.1 mmol/L, and it was 6.2 mmol/L in patients with stage 3 AKI.

During earthquakes, the mortality and morbidity rates associated with Crush Syndrome are lower among children, likely due to their smaller physique, which results in less impact.[7] In our study, the incidence of Crush Syndrome in pediatric patients was 25.2% (28 out of 111), compared to 20% (100 out of 499) in adult patients, with pediatric patients experiencing fewer renal complications. The incidence of Crush Syndrome with stage 1 AKI or higher was 33% (33 out of 100) in adults, whereas it was 32.1% (9 out of 28) in the pediatric group. Hemodialysis treatment was administered to 24% (24 out of 100) of the adult Crush Syndrome patients and 17.8% (5 out of 28) in the pediatric group. At discharge, no patient in either group required hemodialysis.

The incidence of Crush Syndrome-related AKI and the need for dialysis have varied in different studies. In a report from Bam, Iran, 6.5% of 1,975 hospitalized patients required dialysis, whereas 54% needed hemodialysis in the Kobe earthquake, and 75% in the Marmara earthquake. In the Kobe earthquake, the need for hemodialysis was directly associated with increased serum CK levels, with 84% of patients having CK levels above 75,000 units/l requiring dialysis, compared to 39% with lower CK levels.[8,9,10] In our study, the high incidence of AKI (32.8%, 42 out of 128) and the frequency of hemodialysis requirement among AKI patients (69%, 29 out of 42) may reflect the earthquake's severity and the affected victim count. Twenty-four adults and five pediatric patients underwent dialysis in our study.

For Crush Syndrome, intermittent hemodialysis is recommended over other renal replacement methods. Compared to other methods, intermittent hemodialysis is most effective in excreting potassium, one of the primary causes of mortality.[11] Dialysis is initiated for typical indications such as volume overload, hyperkalemia, severe acidosis, and uremia. Due to the high risk of fatal hyperkalemia, frequent hemodialysis (two or even three times a day) may be indicated for patients with Crush Syndrome. Intermittent dialysis was employed in our study.

In Crush Syndrome, the use of fasciotomy is highly controversial. It has been shown that in selected cases, fasciotomy significantly contributes to the recovery of extremities within the first 24 hours. However, when performed in later stages, fasciotomy significantly increases the rates of sudden early mortality and long-term morbidity. In our study, 24 (18.7%) of 128 patients with Crush Syndrome underwent fasciotomy, and 11 (8.5%) underwent amputation. One patient (4.8%, 1/24) died following fasciotomy. When comparing the demographic and laboratory data of patients who were candidates for amputation to those selected for fasciotomy, CK and ALT levels were statistically significantly higher in the fasciotomy group. This may be due to impaired circulation in patients who underwent amputation, whereas circulation continued in patients who opted for fasciotomy. In a report from Bam, Iran, 70 of 200 patients (35%) with Crush Syndrome and acute kidney injury underwent fasciotomy, with no observed increase in morbidity or mortality.[12] In our study, regression analyses showed that neither fasciotomy nor amputation was associated with increased mortality.

In hyperbaric oxygen (HBO) therapy, 100% oxygen at a pressure above atmospheric level is administered in a hyperbaric chamber.[13] Authors have reported that various injuries, including crush injuries, can be treated with HBO therapy.[14,15] In our study, nine patients received hyperbaric therapy; eight recovered after the treatment. After the second hyperbaric session, one patient, who had undergone amputation and fasciotomy on the other leg, died due to septic shock.

Our study found that low systolic blood pressure measured during hospital admission was associated with increased mortality. Although low systolic blood pressure is an expected finding in shock that could lead to increased mortality, this association has not been previously reported in relation to Crush Syndrome. Fluid resuscitation is known to be crucial for patients with Crush Syndrome. Our findings suggest that low systolic blood pressure and increased mortality may be linked to inadequate fluid resuscitation before hospital admission.

One limitation of our study was the inability to measure the pressure exerted on the extremities after the disaster. Another limitation was its execution at a single center. Additionally, the fact that a significant portion of the patients self-transported to our hospital could introduce bias into the morbidity and mortality data concerning Crush Syndrome.

CONCLUSION

Although the regression analysis showed no significant differences due to the small number of deceased patients, elevated levels of CK, BUN, creatinine, K+, AST, ALT, along with lower levels of calcium, platelets, and bicarbonate, could be considered critical factors in the mortality associated with Crush Syndrome upon admission. Our study highlighted that low systolic blood pressure on admission is a risk factor for increased mortality in Crush Syndrome. This finding may contribute to the literature by suggesting the importance of measuring blood pressure under rubble when possible and administering more aggressive fluid therapy to patients with low systolic blood pressure.

Ethics Committee Approval: This study was approved by the Başkent University Adana Hospital Ethics Committee (Date: 25.04.2023, Decision No: E-94603339-604.01.02-226467).

Peer-review: Externally peer-reviewed.

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Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Crush Sendromunda mortaliteye etki eden faktörler

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AMAÇ: Crush Sendromu, büyük ölçekli katastrofik depremlerden sonra morbidite ve mortalitenin en önemli nedenlerinden biridir. Ezilme Sendromu ile ilgili randomize kontrollü bir çalışma bulunmadığından, bu konudaki bilgiler uzmanların deneyimleriyle sınırlıdır. Bu çalışmanın temel amacı, 06 Şubat 2023 tarihinde meydana gelen Pazarcık ve Elbistan depremleri sonrasında depremzedelerin epidemiyolojik, demografik özelliklerini, klinik sonuçlarını ve mortalite faktörlerini analiz etmektir

GEREÇ VE YÖNTEM: Bu kesitsel ve gözlemsel retrospektif çalışmada, 6 Şubat - 30 Nisan 2023 tarihleri arasında merkezimize başvuran 610 depremzede değerlendirildi. Bu hastalar arasında Crush Sendromu olan 128 hasta çalışmaya dahil edildi. Hastalara ait bilgiler, hastaneye yatışları sırasında hastane kayıtlarından ve sevk edildiklerinde ulusal kayıtlardan elde edildi. Birincil sonucumuz mortalite için risk faktörlerini belirlemekti. Demografik ve laboratuvar verileri akut böbrek hasarı evrelerine göre karşılaştırıldı; mortaliteyi etkileyen faktörler regresyon analizi ile belirlendi.

BULGULAR: 128 Crush Sendromu hastasının (100 yetişkin, 28 çocuk) 64'ü kadındı. AKI oranı %32.8 idi. AKI hastaları arasında hemodiyaliz gereksinimi sıklığı %69 ve mortalite oranı %14.2 idi. Ölüm oranı Crush Sendromu olanlarda %4.6 iken, Crush Sendromu olmayan depremzedelerde %3.9 (19/482) idi. (p: 0.705) Çarpıcı bir şekilde, Crush sendromlu hastalarda mortaliteyi önemli ölçüde etkileyen sadece başvuru sırasındaki düşük sistolik kan basıncıdır. (HR: 1.088, p: 0.021 %95 C.I.)

SONUÇ: Çalışmamız, başvuru sırasındaki düşük sistolik kan basıncının Crush Sendromlu hastalarda artmış mortalite için önemli bir risk faktörü olduğunu vurgulamıştır. Bu sonuç, enkaz altında kan basıncının ölçülmesi ve düşük sistolik kan basıncı olan hastalara daha agresif sıvı tedavisi verilmesi konusunda literatüre katkı sağlayabilir.

Anahtar sözcükler: Crush Sendromu, Pazarcık, Elbistan Depremi, Renal Afet

Ulus Travma Acil Cerrahi Derg 2024;30(3):174-184 DOI: 10.14744/tjtes.2024.20532