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Prognostic factors of crush syndrome and survival in elderly earthquake survivors: a retrospective study after the 2023 Turkey disaster

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Abstract

The 2023 Kahramanmaraş earthquake in southern Turkey exposed critical knowledge gaps in trauma complications among geriatric populations. Limited data exist on injury patterns, systemic sequelae, and outcomes in elderly earthquake survivors, particularly those developing crush syndrome. This study analyzes clinical profiles, complications, and mortality risks in elderly patients (≥ 65 years), comparing those with and without crush syndrome to identify age-specific vulnerabilities. This study was conducted as a single-center retrospective study. 138 patients aged 65 and over who were hospitalized with earthquake-related injuries between February and March 2023 were analyzed, and patients with and without earthquake-related crush syndrome were compared. Demographic, clinical, and laboratory data were used. Of the 138 patients included in the study, 63.8% (n=88) were female, and the mean age was 73.3 ± 7.7 years. 42% (n: 58) of the patients developed crush syndrome. A total of 44.2% underwent surgery, 42.0% developed crush syndrome, 73.9% were discharged, and 8.7% died. In those with crush syndrome, calcium ($p=0.03$), platelet ($p=0.02$), lymphocyte ($p=0.05$) levels were lower; lactate dehydrogenase ($p<0.01$), creatinine kinase ($p<0.01$), white blood cell ($p<0.01$), neutrophil ($p<0.01$), monocyte ($p=0.05$) levels were higher and found to be statistically significant. In addition, crush syndrome was seen more in those with upper extremity fractures ($p=0.01$) and acute renal failure ($p=0.02$), hemodialysis ($p=0.01$), fasciotomy ($p=0.01$), and amputation ($p<0.01$) were more common in those with crush syndrome. The study highlights significant differences in clinical and laboratory parameters among elderly earthquake survivors with crush syndrome, including higher rates of acute renal failure, hemodialysis, and surgical interventions. These findings underscore the critical need for early recognition and targeted management of crush syndrome in geriatric populations during disaster responses.

Key words: crush syndrome, earthquake, geriatrics, trauma.

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Introduction

On February 6, 2023, two catastrophic earthquakes struck southern Turkey, both centered in Kahramanmaraş province. The first, occurring at 4:17 am local time, registered a moment magnitude (Mw) of 7.7 with a focal depth of 8.6 km and an epicenter in Pazarcık district. Nine hours later, a second earthquake of Mw 7.6, with a focal depth of 7 km, hit Elbistan district at 1:24 pm. These unprecedented seismic events, among the strongest in recent history, devastated 11 provinces, affecting approximately 14 million people – 16% of Turkey's population. As of June 2023, the confirmed death toll reached 50,783, including 7,302 foreign nationals, with 115,353 injured. The earthquakes caused exceptionally high dead-at-scene rates (coded black in disaster triage) and widespread crush syndrome among survivors rescued from debris. Many injured individuals, suffering from traumatic injuries and crush-related complications, were urgently transferred to nearby healthcare facilities, highlighting the immense scale of destruction and the ensuing humanitarian crisis.¹ Crush Syndrome

(CS) is a medical disorder characterized by manifestations that extend beyond the localized site of tissue compression, often triggering system-wide effects.² In this condition, damage to muscle cells leads to the disruption of muscle cell integrity, resulting in the leakage of intracellular components such as myoglobin, muscle-derived enzymes (e.g., creatine kinase, lactate dehydrogenase, aldolase, and aminotransferases), and electrolytes into the bloodstream. This process can precipitate severe complications, including kidney injury from myoglobinuria, life-threatening hyperkalemia, circulatory shock, coagulopathies, respiratory failure, and multi-organ failure. While the hallmark presentation classically involves a triad of muscle pain, dark urine from myoglobinuria, and markedly elevated muscle enzyme levels, the intensity and progression of these symptoms may exhibit significant variability among patients.^{3,4} This study aimed to investigate the prognostic factors influencing outcomes in elderly patients injured following the February 6th earthquake, as well as to provide insights into demographic characteristics, injury patterns, and clinical parameters that significantly affect recovery and survival rates.

Materials and Methods

Ethical considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and the Good Clinical Practice guidelines. Ethical approval was obtained from the Non-Interventional Clinical Ethics Committee of Mersin University (decision number: 2025/622). Since this was a retrospective study, informed consent was not required. This was a retrospective, single-center, observational study conducted in the Internal Medicine Clinic of Mersin City Hospital, and data were obtained from the hospital's electronic medical information system.

Study design

The study included 138 earthquake-affected patients aged ≥ 65 years who were admitted to the Emergency Department (ED) of a tertiary education and research hospital in Mersin province, Türkiye, between February 6 and February 28, 2023.

Operational definition of crush syndrome

For the purpose of this retrospective analysis, Crush Syndrome was operationally defined as a history of prolonged entrapment or crush injury followed by the development of Acute Kidney Injury (defined by KDIGO criteria) or a significant elevation in Creatine Kinase levels (e.g., >5 times the upper limit of normal or >5000 U/L) within the first 48 hours of admission.

Patient inclusion

Patients were initially evaluated in the ED, and those requiring further treatment were hospitalized in inpatient wards. Only patients who presented directly to the ED of the study hospital and were not transferred from other facilities in the earthquake zone were included.

Sample size

A total of 138 hospitalized patients aged ≥ 65 years with complete biochemical test results were included in the study. Patients with missing laboratory data or incomplete clinical information were excluded. Among these, 58 patients (35 women,

23 men) had crush syndrome, and 80 patients (53 women, 27 men) did not.

Data collection

Data on age, gender, injury type, and injury site were collected retrospectively. Laboratory parameters included serum glucose, sodium, potassium, calcium, phosphorus, urea, creatinine, Creatine Kinase (CK), myoglobin, Lactate Dehydrogenase (LDH), C-Reactive Protein (CRP), and complete blood count. All data were carefully reviewed and recorded for analysis.

Statistical analyses

Statistical analyses were performed using SPSS for Windows Version 22.0 (IBM Corp., Armonk, NY, USA). Normality was evaluated using histograms, probability plots, and the Shapiro–Wilk test. Continuous variables were presented as mean \pm Standard Deviation (SD) or median (min–max), and categorical variables as numbers and percentages. Comparisons between patients with and without crush syndrome were made using the Mann-Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables. To identify independent predictors of crush syndrome, age- and gender-adjusted logistic regression models were performed. A p-value <0.05 was considered statistically significant.

Results

The mean age of the patients was 73.3 ± 7.7 years, and 63.8% were female. Among patients with crush syndrome, the mean age of 72.7 ± 8.3 years. The median time spent under rubble was 57 hours, and the median hospital stay was 5.5 days. A total of 44.2% underwent surgery, 42% developed crush syndrome, 73.9% were discharged, and 8.7% died. Clinical and demographic characteristics are presented in Table 1. Lower extremity fractures were the most common trauma type among all patients (48.6%). However, among patients with crush syndrome, upper extremity fractures were most common (46.6%). Trauma-related data are shown in Figure 1.

In patients with crush syndrome, calcium ($p=0.03$), platelet ($p=0.02$) and lymphocyte ($p=0.05$) levels were significantly lower. LDH ($p<0.01$), CK ($p<0.01$), WBC ($p<0.01$), neutrophil ($p<0.01$), and monocyte ($p=0.05$) levels were significantly higher.

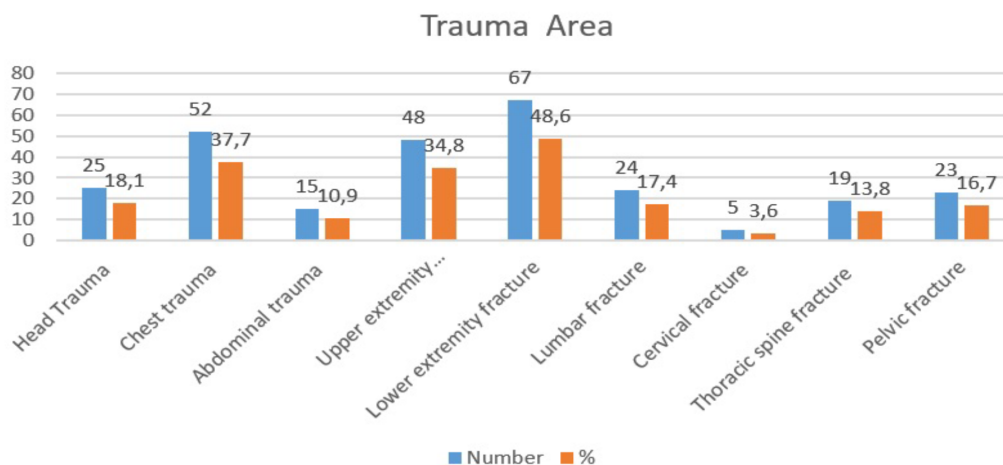


Figure 1. Data of Trauma Area.

Crush syndrome was also significantly more common in patients with upper extremity fractures ($p=0.01$), acute renal failure ($p=0.02$), hemodialysis ($p=0.01$), fasciotomy ($p=0.01$), and amputation ($p<0.01$). Due to the large number of analyzed clinical and laboratory parameters, the full comparative dataset exceeded one page. According to journal guidelines, the complete table was moved to the Supplementary Material (*Supplementary Table 1*), while Table 2 in the main text includes only parameters that reached statistical significance. Age- and gender-adjusted logistic regression analysis showed that WBC (OR: 1.2, 95% CI: 1.1-1.3, $p<0.01$), platelet (OR: 1.0, 95% CI: 0.9-1.0, $p=0.02$), neutrophil (OR: 1.3, 95% CI: 1.2-1.4, $p<0.01$), lymphocyte (OR: 0.4, 95% CI: 0.2-0.8, $p<0.01$), monocyte (OR: 4.7, 95% CI: 1.5-15.1, $p<0.01$), LDH (OR: 1.0, 95% CI: 1.0-1.1, $p<0.01$), CK (OR: 1.0, 95% CI: 1.0-1.1, $p<0.01$), upper extremity fracture (OR: 2.2, 95% CI: 1.0-4.5, $p=0.03$), acute renal failure (OR: 3.5, 95% CI: 1.5-8.2, $p=0.03$), hemodialysis (OR: 6.0, 95% CI: 1.3-29.7, $p=0.02$), and fasciotomy (OR: 7.7, 95% CI: 1.5-38.9, $p=0.01$) were significant predictors. A fully corrected version of Table 3 is presented below.

Table 1. Clinical and demographic information of patients.

Features	N=138 (%)
Female	88 (63.8)
Male	50 (36.2)
Age (year)	73.3±7.7
Time spent in the wreck(hour) median (min-max)	57 (6-322)
Hospitalization days median(min-max)	5.5 (1-63)
Surgery	61 (44.2)
Fasciotomy	10 (7.2)
Amputation	5 (3.6)
Number of patients in intensive care	34 (24.6)
Discharged (%)	102 (73.9)
Referral to another hospital (%)	24 (17.4)
Mortality (%)	12 (8.7)
Hemodialysis mean±SD	10 (7.2)
Acute renal failure mean±SD	32 (23.2)
Crush Syndrome mean±SD	58 (42.0)

Table 2. Statistically significant demographic, laboratory, and clinical variables associated with crush syndrome (shortened version).

Features	Crush Syndrome (n=58, none)	No Crush Syndrome (n=80, none)	p
Blood calcium (mg/dL)	8.4±0.6	8.6±0.5	0.03
Platelet count ($\times 10^3/\mu\text{L}$)	228.4±69.8	263.6±91.8	0.02
Absolute lymphocyte count ($\times 10^3/\mu\text{L}$)	1.3±0.6	1.5±0.7	0.05
LDH (U/L)	494.5±262.8	286.2±174.7	<0.01
CK (U/L)	972.7±123.9	359.1±267.4	<0.01
White blood cell count ($\times 10^3/\mu\text{L}$)	14.1±5.5	10.1±3.5	<0.01
Neutrophil count ($\times 10^3/\mu\text{L}$)	11.8±5.3	7.5±3.3	<0.01
Monocyte count ($\times 10^3/\mu\text{L}$)	0.8±0.4	0.7±0.3	0.05
Upper extremity fracture	27 (46.6%)	21 (26.3)	0.01
Acute renal failure	20 (34.5)	12 (15.0)	0.02
Hemodialysis	8 (13.8)	2 (2.5)	0.01
Fasciotomy	8 (13.8)	2 (2.5)	0.01
Amputation	5 (8.6)	0 (0)	<0.01

Table 3. The age- and gender-adjusted logistic regression analysis among elder patients who with Crush Syndrome

Features	OR (95% CI)	p
Age	1.0 (0.9-1.0)	0.7
Gender	1.2 (0.6-2.5)	0.5
White blood cell count	1.2 (1.1-1.3)	<0.01
Platelet count	1.0 (0.9-1.0)	0.02
Absolute neutrophil count	1.3 (1.2-1.4)	<0.01
Absolute lymphocyte count	0.4 (0.2-0.8)	<0.01
Absolute monocyte count	4.7 (1.5-15.1)	<0.01
Blood calcium level	1.3 (0.6-2.6)	0.03
LDH	1.0 (1.0-1.1)	<0.01
CK	1.0 (1.0-1.1)	<0.01
Upper extremity fracture	2.2 (1.0-4.5)	0.03
Acute renal failure	3.5 (1.5-8.2)	0.03
Hemodialysis	6.0 (1.3-29.7)	0.02
Fasciotomy	7.7 (1.5-38.9)	0.01

Discussion

The cases presented in this study, which are over 65 years of age, will be examined separately for the first time in the literature and will provide clinicians and healthcare managers with valuable information about the types of injuries, accompanying traumas, surgical treatments applied to patients and patient outcomes. The findings of this study are very important for better preparation for future disasters.

This study evaluates biochemical, clinical and demographic data in elderly patients. The mean age of the patients was 73.3 ± 7.7 , and 63.8% were female and 60.3% of those with crush syndrome were female, the mean age was 72.7 ± 8.3 . Post-earthquake demographic analyses across multiple studies consistently report a female predominance and comparable age ranges among patients seeking medical care. Gürü *et al.* found 124 patients (46.5 ± 17.4 years; 60.5% female) after the February 6 earthquake, while Uz *et al.* (2020) noted 313 earthquake-injured patients (mean age 38.0 years; 60.4% female) following the Aegean earthquake. Similarly, Buyurgan *et al.* documented a mean age of 45.94 years with a female majority post-Marmara earthquake.⁵⁻⁷ In a study by Li Zang *et al.* comparing adults and elderly patients who developed acute renal failure after being injured in the Wenchuan earthquake, the mean age of the 45 elderly cases was 75.2 years.⁸

Advanced age is associated with physiological alterations, including reduced bone density, diminished adipose tissue reserves, atrophy of subcutaneous tissue, and sarcopenia, which collectively increases susceptibility to traumatic injury under equivalent kinetic energy exposure.⁹ In conclusion, elderly individuals exhibit elevated mortality risk from severe trauma during entrapment or prehospital phases. Paradoxically, age-related reductions in skeletal muscle mass may attenuate the likelihood of acute compartment syndrome development in this demographic, leading to lower fasciotomy and amputation rates in the elderly compared to younger cohorts.¹⁰ This sophisticated interpretation is a major discussion point of our study. In our study, it was found that the patients most frequently had lower extremity (48.6%), chest trauma (37.7%) and upper extremity (34.8%) traumas. In the study by Li Zang *et al.*, extremity fractures were found to be 42.2% and thorax trauma was found to be 35.6% in elderly patients.⁸

The incidence of Crush syndrome among earthquake survivors exhibits significant variability, ranging from 2% to 37%, attributable to factors such as compression duration, rescue efficacy, proximity to tertiary care, and post-disaster conditions.¹¹ In this study, Crush syndrome was identified in 42.2% ($n=58$) of patients. The mortality rate was 8.7%, while surgical intervention, fasciotomy, and amputation rates were 44.2%, 7.2%, and 3.6%, respectively. Notably, mortality, amputation, and fasciotomy frequencies were significantly higher in Crush syndrome patients compared to non-affected individuals. In the study by Li Zhang *et al.*, amputation and fasciotomy rates were 34.1% and 32.2%, respectively, in the overall patient cohort, compared to 20.0% and 17.2% among elderly patients. The authors noted that both procedures were significantly less frequent in older adults than in younger individuals.⁸ In another study, the amputation rate in hospitalized patients was 13% and fasciotomy was 13.7%.¹² A comparative analysis of the findings of the present study with those of previous studies reveals that the incidence of amputation and fasciotomy procedures is significantly lower among geriatric patients in comparison to their younger counterparts.

In our study, acute renal failure was observed in 23.2% of patients, while 7.2% required hemodialysis. Although Acute Kidney

Injury (AKI) has been widely reported to be more prevalent among elderly populations,^{10,13,14} the proportion of elderly individuals with nephrological complications in previous disaster settings—such as the Marmara, Bam, and Kashmir earthquakes—ranged only between 2.6% and 5.7%. In contrast, the rate reported following the Wenchuan earthquake was notably higher, at 19.2%.⁸

The incidence of AKI in elderly patients with CS was 36.2%, with 13.7% requiring Hemodialysis (HD). This HD rate is notably lower than those reported in other studies, which may be attributed to early fluid resuscitation, prompt medical intervention, and stricter criteria for dialysis initiation in our cohort. Comparative studies have demonstrated higher HD requirements among CS patients, such as 20.9%,¹² 22.1%,¹⁵ 29.9%¹¹ and 32.1%.¹⁶

The interpretation of our findings is subject to several limitations. Primarily, the retrospective and single-center design restricts the generalizability of the results. Furthermore, the inclusion of only hospitalized survivors introduces an inherent survivor bias, potentially leading to an underestimation of the true incidence and mortality of crush syndrome. We also acknowledge the possibility of missing data for certain parameters due to the challenging disaster context, which may affect statistical power. Finally, unmeasured factors such as pre-existing comorbidities and variations in rescue interventions represent possible confounders that could influence the outcomes. Therefore, our results should be validated by future prospective, multi-center studies.

In our study, patients with crush syndrome exhibited significantly lower calcium, platelet, and lymphocyte levels, while lactate dehydrogenase, creatine kinase, white blood cell, neutrophil, and monocyte levels were significantly elevated. In the logistic regression analysis adjusted for age and sex, several variables demonstrated statistically significant associations: hematological parameters (white blood cell count, platelet count, neutrophil count, lymphocyte count, and monocyte count), clinical conditions (upper extremity fracture, acute renal failure), and interventions (hemodialysis and fasciotomy). These findings align with existing literature, reinforcing the robustness of the observed relationships in similar clinical contexts.^{4,7,8,12}

Conclusions

This study highlights the unique vulnerabilities and clinical outcomes of elderly earthquake survivors (≥ 65 years). High rates of lower limb, chest and upper limb injuries reflect age-related physiologic declines such as sarcopenia and decreased bone density, which increase trauma severity but paradoxically decrease the risk of compartment syndrome, and contribute to lower fasciotomy and amputation rates compared to younger cohorts. Crush syndrome was strongly associated with acute kidney injury, hemodialysis requirement and high mortality, underscoring the critical need for early fluid resuscitation and biochemical monitoring as evidenced by significant biomarker abnormalities (e.g. hypocalcemia, elevated CK/LDH) in affected patients. Despite lower intervention rates, older individuals remain at high risk of death during entrapment, highlighting the urgency of priority rescue and geriatric-specific triage. These findings advocate for the integration of age-adapted protocols into disaster preparedness frameworks, including targeted nephrological support, optimized surgical decision-making, and prehospital education to reduce morbidity and improve outcomes in this vulnerable population. Addressing these gaps is essential for building resilience in aging societies.

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Online supplementary materials

Table 1. Full comparative dataset of demographic, laboratory, and clinical characteristics between patients with and without crush syndrome.

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Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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