ORIGINAL ARTICLE

Pre-hospital fluid resuscitation and return of spontaneous circulation in earthquake victims with cardiac arrest during the first 24 hours after the 2023 Kahramanmaraş earthquakes: Implications for disaster risk management

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ABSTRACT

BACKGROUND: Earthquakes can cause crush injuries and post-extrication deaths. Hyperkalemia, metabolic acidosis, hypovolemia, and circulatory failure are key mechanisms of cardiac arrest in victims at risk of crush syndrome. Although intravenous fluid resuscitation is recommended in disaster care, evidence on resuscitation outcomes remains limited. This study evaluated earthquake victims with cardiac arrest during the first 24 h after the 2023 Kahramanmaraş earthquakes and examined the association between pre-hospital fluid resuscitation, admission metabolic parameters, and return of spontaneous circulation (ROSC).

METHODS: This single-center retrospective study was conducted in the emergency department of a tertiary hospital in Mersin, Türkiye. Adult earthquake victims admitted within the first 24 h who developed cardiac arrest before or after emergency department arrival were included. Patients with fatal head, thoracic, or abdominal injuries or missing data were excluded. Initial admission blood gas values were analyzed. The primary outcome was ROSC.

RESULTS: Thirty-seven patients were included. The mean age was 49.30±18.63 years, and 20 patients (54.1%) were female. Pre-hospital fluid resuscitation was administered to 25 patients (67.6%), with a mean volume of 1540±611 mL. Patients receiving fluids had higher pH and lower lactate, potassium, and base excess values. ROSC occurred in 10 patients (27.0%), all of whom had received fluids (p=0.010).

CONCLUSION: Pre-hospital fluid resuscitation was associated with a more favorable metabolic profile and higher ROSC rates in earthquake-related cardiac arrest. These findings support field-based fluid resuscitation and hyperkalemia management in disaster response planning; however, causality cannot be inferred.

Keywords: Cardiac arrest; crush syndrome; disaster risk management; earthquake; emergency medical services; fluid resuscitation; pre-hospital care; return of spontaneous circulation.

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INTRODUCTION

Türkiye is one of the most earthquake-prone countries because of its active tectonic structure. On February 6, 2023, two major earthquakes (Mw 7.7 and Mw 7.6) centered in Kahramanmaraş affected 11 provinces, causing tens of thousands of deaths and injuries and creating one of the largest disasters in the country's recent history.[1,2]

Among survivors rescued from collapsed buildings, crush syndrome is a major cause of early morbidity and mortality. Prolonged muscle compression followed by reperfusion results in rhabdomyolysis, leading to hyperkalemia, metabolic acidosis, hypovolemia, acute kidney injury, and circulatory failure. These metabolic disturbances are recognized causes of sudden cardiac arrest after extrication, often referred to as "rescue death."[3-7]

Current disaster medicine guidelines recommend establishing intravenous access and initiating isotonic fluid resuscitation as early as possible, preferably before or during extrication, to reduce the severity of crush syndrome and its complications.[7,8] However, clinical evidence evaluating the association between pre-hospital fluid resuscitation and resuscitation outcomes in earthquake victims remains limited.

Following the 2023 Kahramanmaraş earthquakes, many critically injured patients were transported to tertiary hospitals, including victims who experienced cardiac arrest before or shortly after hospital arrival. The present study aimed to evaluate adult earthquake victims who developed cardiac arrest within the first 24 h after the earthquakes and to investigate the association between pre-hospital fluid resuscitation, admission metabolic parameters, and return of spontaneous circulation (ROSC). The findings may also contribute to disaster medical response planning by providing evidence on the potential role of early field-based interventions in reducing preventable deaths after major earthquakes.

MATERIALS AND METHODS

Study Design and Setting

This was a single-center, retrospective observational study conducted in the emergency department of a tertiary training and research hospital. The hospital is the largest healthcare center in Mersin, with a capacity of 1440 beds, and actively provided care for earthquake victims after the February 6, 2023 earthquakes that affected 11 provinces.

The study was conducted in accordance with the principles for retrospective chart review studies in emergency medicine described by Kaji et al.[9]

Patient Selection

Between February 6 and February 17, 2023, a total of 7670 earthquake victims were admitted to the emergency department of our hospital. Of these patients, 7575 were transported by road, 74 by sea, and 21 by air. A total of 1983 patients were hospitalized, 389 were transferred to other hospitals, 874 underwent surgical procedures, and 148 died.

This study included adult earthquake victims aged 18 years or older who were admitted to the emergency department within the first 24 h after the earthquakes and who developed cardiac arrest either in the pre-hospital setting or after emergency department arrival. Patients without major fatal head, thoracic, or abdominal injuries were included. Patients brought by emergency medical services with ongoing cardiopulmonary resuscitation (CPR) and patients who developed cardiac arrest after arrival at the emergency department were evaluated.

Patients younger than 18 years, pregnant patients, patients with obvious severe head trauma, patients with pneumothorax or massive hemothorax detected by lung auscultation or radiological evaluation after ROSC, patients with free fluid on Focused Assessment with Sonography for Trauma, patients with fatal arterial injury, patients brought in cardiac arrest without documented emergency medical service intervention, patients who were already in cardiac arrest on arrival by private means, and patients with missing data were excluded.

Data Sources

Patients were identified by reviewing the hospital information system, emergency medical service case forms, and patient files. During the database search, the ICD code "X34" was used for earthquake victims, and the codes "I46," "I46.0," "I46.9," and "R09.2" were used for cardiac arrest.

Data Collection and Definitions

A standardized study data form was created to ensure systematic data collection and to identify cases with missing information. The following variables were recorded: Age, sex, pre-hospital cardiac arrest status, pre-hospital CPR history, pre-hospital resuscitation duration, pre-hospital fluid resuscitation status and amount, emergency department resuscitation status, emergency department resuscitation duration, emergency department fluid resuscitation status, and initial blood gas parameters.

The blood gas values used in the analysis were the first blood gas measurements obtained at the time of emergency department admission. The evaluated laboratory parameters included potassium, pH, base excess, and lactate.

Outcome Measures

The primary outcome of the study was ROSC, defined as ROSC after CPR. ROSC was accepted when spontaneous circulation was achieved either before emergency department arrival or during resuscitation in the emergency department.

Secondary outcomes included the relationship between pre-hospital fluid resuscitation and admission metabolic parameters, including pH, lactate, potassium, and base excess.

Statistical Analysis

Data were analyzed using Statistical Package for the Social

Table 1. Association between pre-hospital fluid resuscitation and in-hospital mortality among patients who underwent CPR

Parameter	In-hospital outcome		p
	Death	Survived	
No pre-hospital fluid resuscitation+CPR	12 (100.0)	0 (0.0)	0.036
Pre-hospital fluid resuscitation+CPR	17 (68.0)	8 (32.0)	

CPR: Cardiopulmonary resuscitation.

Sciences version 26.0. Descriptive data were presented as numbers, percentage, mean±standard deviation, median, minimum, and maximum values, as appropriate. The distribution of continuous variables was evaluated using the Kolmogorov–Smirnov test. Normally distributed continuous variables were expressed as mean±standard deviation and compared using the independent samples t-test. Categorical variables were analyzed using the Pearson Chi-square test or Fisher's exact test when expected cell counts were low. A $p<0.05$ was considered statistically significant.

Ethical Considerations

Ethics committee approval was obtained from the Toros University Scientific Research and Publication Ethics Committee before the study was conducted (decision no. 70; date: June 5, 2023). Because of the retrospective design of the study, the requirement for informed consent was waived. This study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

A total of 37 patients were included in the study. Of these, 20 patients were female (54.1%), and the mean age was 49.30±18.63 years. Twenty-five patients (67.6%) were transported to the emergency department by emergency medical services, whereas 12 patients (32.4%) presented by private means.

Cardiac arrest occurred in the pre-hospital setting in 14 patients (37.8%), all of whom received pre-hospital CPR by emergency medical service teams. CPR was initiated or continued in the emergency department in 34 patients (91.9%). Among the 14 patients who received pre-hospital CPR, resuscitation was continued in the emergency department in 11 patients, whereas 3 patients were delivered to the emergency department after ROSC in the pre-hospital.

The mean duration of pre-hospital CPR was 17.50±7.00 min, whereas the mean duration of in-hospital CPR was 22.71±10.41 min. When the total duration of pre-hospital and in-hospital CPR was considered, the overall mean CPR duration was 27.49±10.55 min.

The in-hospital mortality rate was 78.4% (n=29), whereas 21.6% of the patients (n=8) survived to hospital discharge (Table 1).

Initial blood gas values obtained at emergency department admission showed a mean pH of 6.96±0.16, mean lactate level of 10.55±2.75 mmol/L, mean base excess of −15.22±3.47, and mean potassium level of 6.56±0.69 mEq/L. Pre-hospital fluid resuscitation was administered to 25 patients (67.6%). The mean amount of fluid administered was 1540±611 mL (Table 2).

When laboratory values were compared according to pre-hospital fluid resuscitation status, patients who received fluid resuscitation had significantly higher pH values and significantly lower potassium, lactate, and base excess values than those who did not receive fluid resuscitation. The pH was higher in the fluid resuscitation group than in the non-fluid group (7.02±0.11 vs. 6.83±0.15, $p<0.001$). Lactate levels were lower in the fluid resuscitation group (9.84±2.62 vs. 12.04±2.48,

Table 2. Demographic, clinical, and laboratory characteristics of the study population

Parameter	Value
Age, years	49.30±18.63
Female sex	20 (54.1)
Mode of admission: EMS	25 (67.6)
Mode of admission: private means	12 (32.4)
Cardiac arrest location: pre-hospital	14 (37.8)
Cardiac arrest location: emergency department	23 (62.2)
Pre-hospital CPR	14 (37.8)
Pre-hospital CPR duration, min	18.46±6.25
Emergency department CPR	34 (91.9)
Emergency department CPR duration, min	22.71±10.41
Pre-hospital fluid resuscitation	25 (67.6)
Pre-hospital fluid volume, mL	1540±611
pH	6.96±0.16
Lactate, mmol/L	10.55±2.75
Potassium, mEq/L	6.56±0.69
Base excess	−15.22±3.47
ROSC achieved	10 (27.0)

Values are presented as mean±standard deviation or n (%). CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services; ROSC: Return of spontaneous circulation.

Table 3. Admission laboratory parameters according to pre-hospital fluid resuscitation status

Laboratory parameter	Fluid resuscitation (n=25)	No fluid resuscitation (n=12)	p
pH	7.02±0.11	6.83±0.15	<0.001
Lactate, mmol/L	9.84±2.62	12.04±2.48	0.023
Potassium, mEq/L	6.39±0.44	6.93±0.97	0.020
Base excess	−13.72±2.31	−18.35±3.46	<0.001

Values are presented as mean±standard deviation. Independent samples t-test was used.

Table 4. Admission laboratory parameters according to return of spontaneous circulation

Laboratory parameter	ROSC achieved (n=10)	ROSC not achieved (n=27)	p
pH	7.09±0.12	6.91±0.14	0.001
Lactate, mmol/L	8.91±3.46	11.16±2.21	0.025
Potassium, mEq/L	6.32±0.58	6.66±0.72	0.196
Base excess	−13.03±2.61	−16.03±3.44	0.017

Values are presented as mean±standard deviation. Independent samples t-test was used. ROSC: Return of spontaneous circulation.

Table 5. Association between pre-hospital fluid resuscitation and return of spontaneous circulation

Pre-hospital fluid resuscitation	ROSC achieved	ROSC not achieved	p
Yes (n=25)	10 (40.0)	15 (60.0)	0.010
No (n=12)	0 (0.0)	12 (100.0)	

Values are presented as n (%). Fisher's exact test was used. ROSC: Return of spontaneous circulation.

p=0.023). Potassium levels were also lower in the fluid resuscitation group (6.39±0.44 vs. 6.93±0.97, p=0.020). Base excess values were lower negative in the fluid resuscitation group (−13.72±2.31 vs. −18.35±3.46, p<0.001) (Table 3).

ROSC was achieved in 10 patients. Patients with ROSC had significantly higher pH values than those without ROSC (7.09±0.12 vs. 6.91±0.14, p=0.001). Lactate levels were significantly lower in patients with ROSC (8.91±3.46 vs. 11.16±2.21, p=0.025). Base excess values were also lower negative in patients with ROSC (−13.03±2.61 vs. −16.03±3.44, p=0.017). Potassium levels did not differ significantly between patients with and without ROSC (6.32±0.58 vs. 6.66±0.72, p=0.196) (Table 4).

Among patients who received pre-hospital fluid resuscitation, ROSC was achieved in 10 patients (40.0%). In contrast, ROSC was not achieved in any patient who did not receive pre-hospital fluid resuscitation (p=0.010) (Table 5).

DISCUSSION

In this study, we evaluated earthquake victims who developed cardiac arrest during the first 24 h after the February 6, 2023 Kahramanmaraş earthquakes, one of the most destructive recent disasters in Türkiye.[1,2] The main finding was that pre-hospital fluid resuscitation was associated with a more favorable metabolic profile at emergency department admission and a higher rate of ROSC. Patients who received pre-hospital fluid resuscitation had higher pH values and lower lactate, potassium, and base excess values. In addition, ROSC was achieved only among patients who had received pre-hospital fluid resuscitation.

Deaths after earthquakes are generally evaluated in two phases. In the first phase, traumatic injuries caused by building collapse are the leading cause of death. In the second phase, particularly after extrication, crush syndrome becomes a major contributor to morbidity and mortality. Prolonged muscle compression followed by reperfusion may cause potassium, myoglobin, phosphate, and other intracellular contents to enter the systemic circulation, resulting in hyperkalemia, severe metabolic acidosis, hypovolemia, acute kidney injury, circulatory failure, and sudden cardiac arrest.[3,6,7]

Our findings support the clinical importance of early fluid re-

suscitation in earthquake victims at risk of crush syndrome. International recommendations for mass-disaster crush injury management emphasize that intravenous isotonic fluid administration should be initiated as early as possible, preferably before or during extrication, and continued during transport when feasible.[7] In the present study, patients who received pre-hospital fluid resuscitation had lower potassium levels and lower severity of metabolic acidosis at emergency department admission. Although the retrospective design does not allow a causal conclusion, these findings suggest that early volume replacement may be associated with attenuation of severe metabolic disturbances after extrication and reperfusion.

The relationship between metabolic parameters and resuscitation outcomes was also clinically meaningful. Patients with ROSC had higher pH values and lower lactate and base excess values than patients without ROSC. This finding suggests that the severity of tissue hypoperfusion and metabolic acidosis may be closely related to resuscitation success in earthquake-related cardiac arrest. ROSC is widely used as an immediate outcome measure in standardized cardiac arrest reporting, supporting its use as the primary endpoint in the present disaster cohort.[10] In contrast, potassium levels did not differ significantly between patients with and without ROSC. This may be explained by the limited sample size, the presence of advanced hyperkalemia in both groups, or the multifactorial pathophysiology of cardiac arrest in earthquake victims.

One of the most notable findings of the present study was that ROSC was not achieved in any patient who did not receive pre-hospital fluid resuscitation. This result should be interpreted cautiously because patients who received fluids may have had earlier access to emergency medical services, more complete pre-hospital care, shorter untreated intervals, or a more favorable injury profile. Such sources of selection bias and incomplete documentation are particularly relevant in retrospective emergency medicine chart-review studies.[9] Nevertheless, the finding highlights the potential importance of initiating treatment as early as possible in the disaster field.

The present findings are consistent with previous reports from major earthquakes, particularly the 1999 Marmara earthquake, where crush syndrome and hyperkalemia were identified as leading causes of preventable early deaths after extrication. Sever and colleagues demonstrated that early intravenous fluid administration was one of the most effective interventions to reduce the severity of crush syndrome and acute kidney injury in earthquake victims. These observations established the basis for current recommendations advocating fluid resuscitation before or immediately after extrication whenever possible.[11]

Similar observations were reported following the 2020 İzmir earthquake, where early recognition of crush-related metabolic disturbances and prompt supportive treatment were emphasized to improve patient outcomes. Although the number of patients with cardiac arrest in our study was limited, the association between pre-hospital fluid resuscitation, improved admission metabolic parameters, and successful ROSC supports these previous clinical observations.[12]

Rescue death remains one of the most critical and potentially preventable complications following prolonged entrapment. The sudden release of potassium, acids, and other intracellular contents after extrication may precipitate fatal arrhythmias and circulatory collapse. Our findings reinforce the concept that early pre-hospital fluid resuscitation may mitigate these metabolic disturbances and improve the likelihood of successful resuscitation. While causality cannot be inferred from this retrospective study, the results provide additional clinical evidence supporting early field-based fluid administration as an essential component of crush syndrome management.

Limitations

This study has several limitations. First, it was a single-center retrospective study with a limited sample size. Therefore, selection bias could not be fully excluded, and the statistical power of the study was limited. The small number of patients also prevented robust multivariable analysis to adjust for potential confounders.

Second, the study was conducted under extraordinary disaster conditions. During the 1st h after the earthquakes, the emergency department received a very high number of earthquake victims, and healthcare teams were working under mass-casualty conditions. As a result, some pre-hospital and emergency department records may have been incomplete, non-standardized, or less detailed than records obtained under routine clinical conditions. This limitation is inherent to retrospective studies conducted after large-scale disasters.

Third, several clinically important variables could not be evaluated reliably because of incomplete documentation. These included the exact duration of entrapment under rubble, the time from extrication to emergency department admission, the time from cardiac arrest to initiation of CPR, initial cardiac rhythm, transport duration, the exact timing of fluid initiation, fluid type and infusion rate, total pre-hospital medication use, and the severity and anatomical extent of crush injury. These factors may have influenced both metabolic parameters and resuscitation outcomes.

Fourth, although the blood gas values analyzed in this study were the first measurements obtained at emergency department admission, the exact relationship between blood gas sampling, ongoing CPR, and ROSC could not be standardized in all cases. Therefore, the laboratory parameters should be interpreted as admission metabolic status rather than as strictly pre-treatment values.

Fifth, patients who received pre-hospital fluid resuscitation may have differed systematically from those who did not receive fluids. For example, these patients may have had earlier

contact with emergency medical services, better vascular access, shorter transport times, or less severe traumatic injuries. Therefore, the observed association between fluid resuscitation and ROSC should not be interpreted as definitive evidence of causality.

Finally, long-term outcomes such as survival to hospital discharge, neurological status, renal replacement therapy requirement, and late mortality could not be evaluated within the scope of the available dataset. Future multicenter studies with standardized pre-hospital data collection and longer follow-up are needed to confirm these findings and define optimal field treatment protocols.

In our study, data regarding the interval between the onset of pre-hospital cardiac arrest and the initiation of CPR were not available. In addition, information on amputations and the anatomical distribution of injuries was not consistently documented in the medical records because of the extraordinary conditions during the disaster response and, therefore, could not be analyzed.

Despite these limitations, this study has several important strengths. It presents original clinical data from earthquake victims with cardiac arrest during the first 24 h after one of the largest disasters in recent history, a patient population for which published evidence remains extremely limited. The study integrates pre-hospital interventions, admission metabolic parameters, and resuscitation outcomes, providing clinically relevant insights into the management of crush syndrome under real-world disaster conditions. Furthermore, the observed association between pre-hospital fluid resuscitation and successful ROSC highlights the potential value of early field-based interventions and offers practical information for disaster preparedness, emergency medical services, and future disaster response planning.

CONCLUSION

Pre-hospital fluid resuscitation was associated with more favorable metabolic status on emergency department admission and a higher likelihood of ROSC among adult earthquake victims with cardiac arrest during the first 24 h after the 2023 Kahramanmaraş earthquakes. Although causality cannot be established because of the retrospective design and limited sample size, these findings reinforce the importance of early recognition and treatment of crush syndrome in the pre-hospital setting.

Disaster preparedness and response protocols should prioritize rapid intravenous access, early isotonic fluid resuscitation, timely management of hyperkalemia, and field-based stabilization before transport whenever feasible. Strengthening the capacity of emergency medical services, mobile advanced treatment units, and forward medical posts to provide these interventions may reduce preventable deaths following major earthquakes. Future prospective multicenter studies with standardized pre-hospital data collection are needed to validate these findings and define evidence-based protocols for the management of earthquake-related cardiac arrest.

Ethics Committee Approval: This study was approved by the Toros University Scientific Research and Publication Ethics Committee (Date: 05.06.2023, Decision No: 70).

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ORİJİNAL ÇALIŞMA - *ÖZ*

2023 Kahramanmaraş depremlerinden sonraki ilk 24 saatte kardiyak arrest gelişen depremzedelerde hastane öncesi sıvı resüsitasyonu ile spontan dolaşımın geri dönüşü arasındaki ilişki

AMAÇ: Depremler, ezilme yaralanmalarına ve enkazdan çıkarılma sonrası erken ölümlere neden olabilir. Hiperpotasemi, metabolik asidoz, hipovolemi ve dolaşım yetmezliği, crush sendromu riski taşıyan depremzedelerde kardiyak arrestin temel mekanizmalarıdır. Afet bakımı kapsamında intravenöz sıvı resüsitasyonu önerilmesine rağmen, bunun resüsitasyon sonuçlarıyla ilişkisine dair klinik kanıtlar sınırlıdır. Bu çalışmada, 2023 Kahramanmaraş depremlerinden sonraki ilk 24 saat içinde kardiyak arrest gelişen depremzedeler değerlendirildi ve hastane öncesi sıvı resüsitasyonu, başvuru anındaki metabolik parametreler ve spontan dolaşımın geri dönüşü arasındaki ilişki incelendi.

GEREÇ VE YÖNTEM: Bu tek merkezli retrospektif çalışma, Türkiye'nin Mersin ilindeki üçüncü basamak bir hastanenin acil servisinde yürütüldü. Depremlerden sonraki ilk 24 saat içinde başvuran ve hastane öncesinde veya acil servis başvurusu sonrasında kardiyak arrest gelişen erişkin depremzedeler çalışmaya dahil edildi. Ölümcül kafa, toraks veya batın yaralanması olan hastalar ile verileri eksik olan hastalar çalışma dışı bırakıldı. Başvuru anında alınan ilk kan gazı değerleri analiz edildi. Primer sonlanım spontan dolaşımın geri dönüşü olarak belirlendi.

BULGULAR: Çalışmaya 37 hasta dahil edildi. Ortalama yaş 49.30±18.63 yıl olup, 20 hasta (%54.1) kadındı. Hastane öncesi sıvı resüsitasyonu 25 hastaya (%67.6) uygulanmıştı ve ortalama verilen sıvı miktarı 1540±611 mL idi. Sıvı uygulanan hastalarda pH daha yüksek; laktat, potasyum ve baz açığı değerleri daha düşüktü. Spontan dolaşımın geri dönüşü 10 hastada (%27.0) sağlandı ve bu hastaların tamamına hastane öncesi sıvı verilmişti (p=0.010).

SONUÇ: Depreme bağlı kardiyak arrest olgularında hastane öncesi sıvı resüsitasyonu, daha olumlu bir metabolik profil ve daha yüksek spontan dolaşımın geri dönüşü oranları ile ilişkiliydi. Bu bulgular, afet yanıt planlamasında sahada sıvı resüsitasyonu ve hiperpotasemi yönetiminin önemini desteklemektedir; ancak nedensellik çıkarımı yapılamaz.

Anahtar sözcükler: Acil sağlık hizmetleri; afet risk yönetimi; deprem; ezilme sendromu; hastane öncesi bakım; kardiyak arrest; sıvı resüsitasyonu; spontan dolaşımın geri dönmesi.

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