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The Relationship between Admission Characteristics and Prognosis of Patients Diagnosed with Crush Syndrome After Consecutive Kahramanmaraş Earthquakes

Ardışık Kahramanmaraş Depremleri Sonrası Crush Sendromu Tanısı Alan Hastaların Yatış Özellikleri ile Prognozları Arasındaki İlişki

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Abstract

Introduction: Crush syndrome (CS) is the systemic manifestation of rhabdomyolysis due to prolonged continuous pressure on muscle tissue. We aimed to discuss the clinical and laboratory characteristics of the children who were diagnosed with CS, after the consecutive Kahramanmaraş earthquakes.

Methods: Eleven cases followed in the pediatric intensive care unit with the diagnosis of CS were retrospectively evaluated. The patients' files were scanned in detail. Demographic, clinical, and laboratory data were recorded from the files.

Results: The mean age of the patients was 10.45±4.92 years. Seven of the patients were girls and four were boys. Patients were extricated from the rubble between 7 and 48 hours. The mean admission time was 29.9±39.2 hours. Acute kidney injury was present in 9 patients. Renal replacement therapy (RRT) was required in 7 patients. At admission, presence of dark urine, high prism score, high blood uric acid, and lactate levels was associated with the need for RRT. The mean age was significantly higher in the RRT group. Three patients died. The mean lactate and D-dimer levels at admission were found to be significantly higher in patients who died.

Conclusion: Our results show that survival is possible in CS cases with effective and timely treatment approaches. Many parameters at the time of admission are associated with the need for RRT and death. We also found that as the time spent under rubble increases, blood D-dimer and creatinine levels increase, and ionized calcium and albumin levels decrease.

Keywords: Children, crush syndrome, Kahramanmaraş earthquakes, pediatric, pediatric intensive care unit

Öz

Giriş: Crush sendromu (CS), kas dokusunda uzun süreli sürekli baskıya bağlı oluşan rabdomiyolizin sistemik bir sonucudur. Biz bu çalışmada, ardışık Kahramanmaraş depremlerinden sonra CS tanısı konulan çocukların klinik ve laboratuvar özelliklerini tartışmayı amaçladık.

Yöntemler: Çocuk yoğun bakım ünitesinde CS tanısıyla takip edilen 11 vaka geriye dönük olarak değerlendirildi. Hastaların dosyaları ayrıntılı olarak tarandı. Demografik, klinik ve laboratuvar verileri dosyalardan kaydedildi.

Bulgular: Hastaların yaş ortalaması 10,45±4,92 yıl idi. Hastaların 7'si kız, 4'ü erkekti. Hastalar enkaz altından 7 ile 48 saat arasında çıkarılmıştı. Ortalama yatış süresi 29,9±39,2 saatti. Dokuz hastada akut böbrek hasarı mevcuttu. Yedi hastaya renal replasman tedavisi (RRT) gerekti. Yatışta koyu renkli idrar, yüksek prism skoru, yüksek kan ürik asit ve laktat düzeyleri RRT gereksinimi ile ilişkiliydi. Ortalama yaş RRT grubunda anlamlı olarak daha yüksekti. Üç hasta öldü. Yatıştaki ortalama laktat ve D-dimer düzeylerinin ölen hastalarda anlamlı olarak daha yüksek olduğu bulundu.

Sonuç: Sonuçlarımız CS vakalarında etkili ve zamanında tedavi yaklaşımlarıyla sağ kalımın mümkün olduğunu göstermektedir. Kabul anındaki birçok parametre RRT ihtiyacı ve ölümle ilişkilidir. Ayrıca enkaz altında geçirilen süre arttıkça kan D-dimer ve kreatinin düzeylerinin arttığını ve iyonize kalsiyum ve albümin düzeylerinin azaldığını bulduk.

Anahtar Kelimeler: Çocuklar, crush sendromu, Kahramanmaraş depremleri, pediatrik, çocuk yoğun bakım ünitesi

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Introduction

Crush syndrome (CS) is the systemic manifestation of rhabdomyolysis due to prolonged continuous pressure on muscle tissue. CS is characterized by clinical manifestations including acute kidney injury (AKI), hyperkalemia, hypovolemic shock, and muscle necrosis.[1-3] While during revascularisation, diffusion of calcium, sodium, and water into the damaged muscle cells is seen, necrosis of the muscle causes potassium, phosphate, lactic acid, myoglobin, and creatinine kinase to be released from the cell.[4] Myoglobin induces renal injury by incompletely defined mechanisms. CS is typically encountered in sports, accidents, war zones, mining disasters, and natural disasters such as earthquakes.

On February 6, 2023, two consecutive catastrophic earthquakes struck near Kahramanmaraş, Türkiye. These earthquakes registered with magnitudes of 7.7 and 7.6 (Mw) on the Richter scale and were separated by just nine hours.[5] The follow-up and treatment of the majority of the patients extricated from the rubble within the borders of Gaziantep province were carried out in Gaziantep University Medical Faculty Hospital. Patients who developed CS, while in critical clinical condition, were monitored in the pediatric intensive care unit (PICU).

CS is often lethal unless promptly and vigorously treated. For treatment success, experiences with childhood CS need to be shared. The data about CS in children are limited compared to that of adults in literature.[4,6,7] We believe that considering the characteristics of a patient diagnosed with CS at the time of admission will contribute to obtaining more successful results. Thus, we wanted to reveal a possible relationship between the demographic, clinical, and laboratory characteristics of the patients at the time of admission and the subsequent need for renal replacement therapy (RRT) and occurrence of death in this study.

Materials and Methods

Study Design and Study Population

On February 6, 2023, two consecutive catastrophic earthquakes struck the near Kahramanmaraş, Türkiye. The earthquake caused destruction in 11 cities. Gaziantep province was used as a referral center because it is in the earthquake zone where the destruction was experienced while the city center is the least affected place. This study was designed as a retrospective chart review in a 16-bed tertiary PICU. Earthquake victims between the ages of 1 month and 18 years were included in the study.

Patients who did not require PICU did not develop CS were excluded from the study. In this context, 11 patients who were rescued from the rubble within the first week after the earthquake and diagnosed with CS were evaluated. The files of the patients were scanned in detail. Demographic, clinical and laboratory data were recorded from the files. The pediatric risk of mortality (PRISM) scores were calculated for all patients within the first 24 hours of intensive care admission.

Two patients were intubated at the scene; one patient was intubated in the hospital where they were initially admitted; three patients were intubated in our emergency department; and two patients were intubated in the PICU. AKI was detected in 9 patients. Hemodialysis was performed in 7 patients due to anuria and persistent hyperkalemia. In this study, fasciotomy was performed in 7 patients, and amputation 3 patients.

Definitions

CS was diagnosed in these children who had crushing injury to the skeletal muscle, myoglobinuria and/or hematuria, tense and swollen compressed limbs, and peak creatine kinase (CK)>1000 U/L.[6,8-11] CS diagnosis was made using clinical and laboratory features at the time of admission. Hypoxemia was defined as an arterial oxygen saturation of <90% recorded by a portable pulse oximeter or an arterial oxygen tension (PaO_2) <60 mmHg. AKI was defined with the KDIGO renal damage classification.[12] Initially, according to the CS treatment protocol of the unit, intravenous (IV) fluid infusion and alkaline therapy were started for all patients with suspected CS at the first admission. RRT was performed in hyperkalemic, hyperphosphatemic and/or anuric patients unresponsive to medical treatments. Intermittent hemodialysis (IHD) was performed on all patients as RRT. Since there was an issue with providing continuous RRT devices and equipment during the earthquake, IHD was performed on all patients. The patients were divided into two groups: those who were receiving RRT and those who were not. Also, patients were divided into two groups according to the anatomical sites of injury involving single or multiple extremities. The groups were compared in terms of demographic, clinical and laboratory characteristics.

Evaluated Parameters

Clinical and laboratory parameters were closely monitored. Clinically, systolic and diastolic blood pressure, heart rate, respiratory rate, pulse-oximetry monitoring, fluid input, urine output, and body temperature were continually monitored. Complete blood count, renal and liver function tests, CK, urea, creatinine (Cr), uric acid, magnesium (Mg), potassium (K), sodium (Na), and calcium (Ca) were measured. Disseminated intravascular coagulation (DIC) monitoring was performed with follow-ups prothrombin time, active partial thromboplastin time, D-dimer and fibrinogen. Urine, blood, and wound cultures were taken from children with fever.

Whole body computed tomography and X-ray and Doppler ultrasonography of extremities performed for all patient.

Statistical Analysis

Descriptive and frequency statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) for Windows, version 17.0 (SPSS Inc.; Chicago, IL, USA). Chi-square test and Fisher's exact test were used to determine possible statistically significant differences between the categorical variables and are expressed as frequency (percentage). An Independent Student's t-test was used to compare continuous parametric variables, and the results were expressed as mean ± standard deviation. The Mann-Whitney U test was used to compare continuous non-parametric variables, and the results were expressed as median (minimum-maximum). Correlation coefficients and statistical significance were calculated using the Pearson test for normally distributed variables and the Spearman test for non-normally distributed variables. A statistically significant difference was defined as p-value <0.05.

Ethical Dimension of the Study

Ethical approval was obtained from Gaziantep University Clinic Research Ethics Committee (decision no: 2023/305, date: 04.10.2023).

Results

Eleven patients who were observed in the PICU and diagnosed with CS after the earthquake were included in the study. During this period, only CS patients were admitted to the PICU. Patients were transferred to other intensive care units. The mean age of the patients was 10.45±4.92 years (range: 3-18 years). 7 of the patients were girls and 4 were boys. Patients were extracted from the rubble between 7 and 48 hours (median, 16 hours). The mean admission time was 29.9±39.2 (range: 1-120 hours). The mean PRISM score of the patients was 48.18±19.1 at admission. Four patients were in shock at the time of admission. Inotropic/vasopressor drugs were used in 5 patients. Dark urine was present in 8 (72.3%) patients upon admission. The mean CK, urea, Cr, and uric acid levels of the patients at admission were 84068±91297 (U/L), 91.4±42.1 (mg/dL), 1.68±0.92 (mg/dL), and 13.1±6.1 (mg/dL), respectively (Table 1).

There were lower extremity injuries in 10 patients, thoracic injuries in 2 patients, cranial injuries in 2 patients, and upper extremity injuries in 1 patient. Five patients had multiple areas of damage. Patients with single and multiple extremity injuries were compared for demographic, clinical and laboratory characteristics (Table 2). No significant differences were found for any parameters.

AKI was present in 9 patients. Two of these patients showed improvement with IV hydration. RRT was performed for seven patients. Three of these patients who underwent RRT died. These patients died due to CS and multiple trauma. The patients were examined in terms of the relationship between their findings at admission and the need for RRT (Table 3).

Table 1. Demographic, clinical and laboratory findings of the patients at admission

Clinical and demografical features		
Categorical parameters	**n**	**%**
Sex (male)	4	36.5
Sex (female)	7	63.5
Dark urine	8	72.3
Shock*	4	36.5
Hypoxemia	5	45.5
Site of injury**		
Lower extremity	10	90.1
Thoracic injuries	2	18.2
Cranial injuries	2	18.2
Upper extremity	1	9.1
Continuous parameters	**Mean ± SD**	**Min-max**
Age (years)	10,45±4,92	3-18
PRISM score	48.18±19.1	6-64
Time for admission (hours)	29.9±39.2	1-120
Time spent under rubble (hours)	18.5±12.8	7-48
Laboratory findings	**Mean ± SD**	**Min-max**
Hct (%)	40.9±13.8	23.4-61.5
Leukocyte (/mm^3)	27678±11150	9480-44220
Platelet (/mm^3)	329090±170379	75000-599000
CK (U/L)	84068±91297	1651-234034
AST (U/L)	1477±1570	78-4691
ALT (U/L)	548±540	21-1480
LDH (U/L)	6129±5772	582-17640
Urea (mg/dL)	91.4±42.1	41-174
Cr (mg/dL)	1.68±0.92	0.43-3.11
Uric acid (mg/dL)	13.1±6.1	4.8-23.5
ICa (mg/dL)	1.1±0.2	0.6-1.5
Phosphorus (mg/dL)	9.1±4.6	3.9-19.5
Potassium (mEq/L)	6.1±1.7	3.6-9.5
Sodium (mEq/L)	136±11	125-164
Magnesium (mEq/L)	2.5±0.9	1.5-4.9
D-dimer (µg/L)	12.2±9.5	4.1-35.2
Lactate (mmol/L)	6.2±6.4	0.8-20
Albumin (gr/L)	27.6±10.2	8-41

*: Distributive shock, **: Some patients had injuries in more than one area, CK: Creatine kinase, AST: Aspartat aminotransferase, ICa: Ionized calcium, ALT: Alanine aminotransferase, LDH: Lactate dehydrogenase, Cr: Creatinine, SD: Standard deviation

The need for RRT was significantly increased in patients with dark urine detected at admission (p=0.024). The mean age was significantly higher in the RRT group (p=0.003). RRT was performed in all male patients. The mean PRISM score was significantly higher in the RRT group (p=0.042). The mean uric acid (p=0.026) and lactate levels (p=0.045) were found to be significantly higher for patient who had undergone RRT. Although the mean CK, LDH, and D-dimer levels were higher in the RRT group, this difference was statistically borderline (p=0.050, p=0.051, p=0.059 respectively). Although all other

Table 2. Comparison of patients with single and multiple extremity injuries

Parameters	Single extremity injuries (n=6)	Multiple extremity injuries (n=5)	p
Age (year)	10±4 (4-16)	11±6 (3-19)	0.756
Sex (M/F)	3/3	1/4	0.545
Time to salvage (h)	17.40±9.55 (7-26)	19.60±16.68 (7-48)	0.804
Time before admission (h)	47.00±49.74 (12-120)	12.80±16.16 (1-41)	0.182
Dark urine	4	4	0.576
Shock*	2	2	0.652
Hypoxemia	3	2	0.608
Renal failure	5	4	0.545
Hct (%)	43.26±16.80	38.04±10.09	0.559
Leukocyte (/mm^3)	30345±13025	24478±8675	0.413
Platelet (/mm^3)	383333±138056	264000±197582	0.269
CK (U/L)	94057±90694	69085±103911	0.697
AST (U/L)	1703±1771	1205±1440	0.627
ALT (U/L)	612±556	469±573	0.685
LDH (U/L)	5459±4972	6930±7135	0.697
Urea (mg/dL)	94.50±43.16	87.60±45.53	0.802
Cr (mg/dL)	1.59±0.93	1.81±1.00	0.720
Uric acid (mg/dL)	14.28±5.56	11.52±7.03	0.484
ICa (mg/dL)	1.14±0.24	0.93±0.16	0.131
Phosphorus (mg/dL)	10.42±5.56	7.46±3.14	0.320
Potassium (mEq/L)	6.82±1.73	5.06±1.12	0.084
Sodium (mEq/L)	131.17±4.83	141.80±14.79	0.129
Magnesium (mEq/L)	2.73±1.24	2.18±0.55	0.382
D-dimer (µg/L)	10.41±5.99	14.86±13.95	0.500
Lactate (mmol/L)	5.92±7.37	6.54±5.77	0.881
Albumin (gr/L)	28.83±10.19	26.00±11.07	0.669
Hyperkalemia	5	3	0.545
Hyomagnesemia	6	4	0.455
Hyponatremia	5	2	0.242
Hypocalcemia	5	4	0.727
Fluid bolus	6	5	Null
O_2 suplementation	6	5	Null
Mechanicalventilation	4	4	0.576
Fasciotomy	5	2	0.242
Amputation	2	1	0.576
RRT	4	3	0.652
Inotrop-vasopressor	3	2	0.608
Nutrition (E/TPN)	0/6	0/5	Null
Length of stay in PICU	19.4±8.3 (6-27)	9.8±9.3 (2-23)	0.123
Outcome (Ex)	1	2	0.545

*Distributive shock, PICU: Pediatric intensive care unit, E/TPN: enteral/total paranteral nutrition, CK: Creatine kinase, AST: Aspartat aminotransferase, ICa: Ionized calcium, ALT: Alanine aminotransferase, LDH: Lactate dehydrogenase, Cr: Creatinine, RRT: Renal replacement therapy, Hct: Hematocrit

laboratory parameters were worse in the RRT group, no significant difference was found in the outcomes measured.

In patients who did not undergo RRT, the CK level decreased below 1000 U/L within an average of 9±5.19 days. In patients who underwent RRT and survived, CK levels decreased below 1000 U/L within an average of 13.96±1.4 days.

Despite all treatments administered in accordance with the CS treatment protocol, three patients died. The factors that may affect survival were examined in detail (Table 4). There was no significant association between demographic characteristics and survival. The mean lactate (p<0.001) and D-dimer (p=0.039) levels at admission were found to be significantly higher in patients who died. RRT was administered to all patients who died.

Correlation analysis was performed for parameters that may have been affected by the duration of stay under rubble and PICU admission duration (Table 5). We found that as the time spent under rubble increased, blood D-dimer and creatinine levels increased, and iCa and albumin levels decreased. Also, a significant increase in hematocrit was detected as the time for admission to PICU increased. This may be related to hemoconcentration due to delayed fluid replacement.

Table 3. Evaluation of the relationship between the findings at admission and the requirement for RRT

Parameters	**RRT (+)**	**RRT (-)**	**p**
Clinical and demografical features			
Categorical parameters	**n (%)**	**n (%)**	
Sex (male)	4 (100)	0 (0)	NS
Sex (female)	3 (42.9)	4 (57.1)	0.194
Dark urine	7 (87.5)	1 (12.5)	0.024
Shock*	4	0	NS
Hypoxemia	4	1	0.545
Continuous parameters	**Mean ± SD**	**Mean ± SD**	
Age (years)	13.285±3.450	5.5±2.380	**0.003**
PRISM score	61 ±3.464	40.857±20.594	**0.042**
Time spent under rubble (hours)	23.333±13.822	11.25±7.847	0.155
Time for admission (hours)	42.833±47.595	10.5±3.109	0.220
LOS in PICU (days)	19±11.619	11±6.377	0.604
Laboratory findings	**Mean ± SD**	**Mean ± SD**	
Hct (%)	44.5±14.8	34.5±10.2	0.267
Leukocyte (/mm^3)	25941±12365	30717±9448	0.523
Platelet (/mm^3)	325000±183800	336250±170562	0.923
CK (U/L)	127859±93939	18382±36645	**0.050**
AST (U/L)	2033±1742	504±407	0.125
ALT (U/L)	744±590	202±160	0.112
LDH (U/L)	8621±5808	1764±1919	**0.051**
Urea (mg/dL)	96.6±46.3	82.3±38.1	0.614
Cr (mg/dL)	2.10±0.93	1.14±0.67	0.143
Uric acid (mg/dL)	15.9±5.1	7.9±4.1	**0.026**
ICa (mg/dL)	1.1±0.27	1.1±0.11	0.515
Phosphorus (mg/dL)	10.9±4.5	5.8±3.3	0.084
Potassium (mEq/L)	6.7±1.6	4.86±1.05	0.083
Sodium (mEq/L)	136±12	137±9	0.879
Magnesium (mEq/L)	2.7±1.1	2.1±0.5	0.296
D-dimer (µg/L)	16.7±10.1	5.41±0.8	**0.059**
Lactate (mmol/L)	9.1±6.4	1.2±0.7	**0.045**
Albumin (gr/L)	25.9±12.3	30.5±4.5	0.495

*Distributive shock, CK: Creatine kinase, AST: Aspartat aminotransferase, ICa: Ionized calcium, ALT: Alanine aminotransferase, LDH: Lactate dehydrogenase, Cr: Creatinine, Hct: Hematocrit, RRT: Renal replacement therapy

Discussion

Support of airway, breathing, circulation should be provided in extrication and on scene management. Amputation in the field may be required for some patients. In these patients, adequate IV fluid infusion should be given as soon as possible. The study reported that fluid resuscitation during the initial two days is critical for preventing AKI.[13] Two patients were intubated at the scene, 1 patient was intubated in the hospital where they were firstly admitted, 3 patients were intubated in our emergency department and 2 patients were intubated in the PICU. Oxygen supplementation was given to all patients after they were removed from the rubble. The first fluid therapy was started in the emergency department for almost all of the patients.

Administration of IV fluid initiated in the field should be continued with close monitoring of urine output in hospital follow-up. Clinical examination and laboratory studies should

Table 4. Evaluation of the factors that may have an impact on outcomes

Parameters	**Survivals**	**Non-survivals**	
Clinical and demografical features			
Categorical parameters	**n (%)**	**n (%)**	**p**
Sex (male)	3 (75)	1 (25)	0.98
Sex (female)	5 (71.4)	2 (28.6)	
Mechanical ventilation	5 (62.5)	3 (37.5)	0.491
Inotropic use	2 (40)	3 (60)	**0.061**
RRT	4 (62.5)	3 (37.5)	0.236
Fasciotomy	5 (62.5)	2 (37.5)	1.000
Amputation	3	0	NS
Wound infection	4	0	NS
Continuous parameters	**Mean ± SD**	**Mean ± SD**	**p**
Age (years)	8.8±4.2	14.6±4.5	**0.080**
PRISM score	45.37±21.82	55.66±4.93	0.453
Extracation time (hours)	16.3±8.7	23.7± 21.6	0.438
Time for admission (hours)	40,142±43,502	6±5.567	0.227
LOS in PICU (days)	18.5±9.38	9.66±12.42	0.503
Laboratory findings	**Mean ± SD**	**Mean ± SD**	**p**
Hct (%)	40.7±15.1	41.2±12.4	0.959
Leukocyte (/mm^3)	27487±10697	28186±14851	0.932
Platelet (/mm^3)	352250±158098	267333±223150	0.491
CK (U/L)	70953±83770	136527±137895	0.441
AST (U/L)	1511±1538	1384±2007	0.912
ALT (U/L)	542±485	560±796	0.965
LDH (U/L)	5399±4958	8071±8528	0.523
Urea (mg/dL)	94.3±42.3	83.3±49.7	0.720
Cr (mg/dL)	1.58±0.84	1.95±1.26	0.587
Uric acid (mg/dL)	11.2±5.1	17.8±7.1	0.110
ICa (mg/dL)	1.1±0.1	1.1±0.4	0.978
Phosphorus (mg/dL)	7.9±3.7	12.1±6.4	0.208
Potassium (mEq/L)	5.7±1.3	6.9± 2.5	0.325
Sodium (mEq/L)	135±7	139±21	0.580
Magnesium (mEq/L)	2.2±0.5	3.2±1.6	0.169
D-dimer (µg/L)	9.2±5.4	24.1±15.7	**0.039**
Lactate (mmol/L)	2.9±2.4	15.1±4.7	**<0.001**
Albumin (gr/L)	27.1±7.3	28.6±18.1	0.836

CK: Creatine kinase, AST: Aspartat aminotransferase, ICa: Ionized calcium, ALT: Alanine aminotransferase, LDH: Lactate dehydrogenase, Cr: Creatinine, RRT: Renal replacement therapy, PRISM: The pediatric risk of mortality, LOS: Length of stay, PICU: Pediatric intensive care unit, Hct: Hematocrit

Table 5. The time spent under rubble and the time for admission to PICU related correlation analysis

	Time spent under rubble		Time for admission	
Parameters	**r**	**p**	**r**	**p**
Hct[a]	0.118	0.745	**0.720**	**0.019***
Leukocyte[a]	-0.544	0.104	-0.062	0.866
Platelet[a]	-0.271	0.432	0.176	0.627
CK [a]	-0.090	0.818	0.035	0.928
AST[a]	0.093	0.798	0.457	0.184
ALT[a]	0.148	0.683	0.479	0.161
LDH[a]	-0.013	0.973	0.323	0.362
Urea[a]	0.602	0.065	0.095	0.795
Cr[a]	**0.702**	**0.024***	0.366	0.299
Uricasid[a]	0.099	0.786	0.224	0.534
iCalcium[a]	**-0.749**	**0.013***	-0.142	0.695
Phosphorus[a]	0.074	0.839	0.222	0.537
Potassium[a]	-0.155	0.668	0.098	0.788
Sodium[a]	0.509	0.133	-0.242	0.500
Magnesium[a]	-0.256	0.476	0.043	0.906
D-dimer[a]	**0.784**	**0.012***	-0.072	0.853
Lactate[a]	0.270	0.450	-0.168	0.643
Albumin[a]	**-0.698**	**0.025***	-0.089	0.808
Fasciotomy[b]	**0.647**	**0.043***	0.535	0.111
Amputation[b]	0.038	0.916	0.267	0.456
RRT[b]	0.534	0.108	0.178	0.622
Mortality[b]	0.038	0.916	-0.610	0.061

[a]: Pearson correlation test; [b]: Spearman correlation test, CK: Creatine kinase, AST: Aspartat aminotransferase, ICa: Ionized calcium, ALT: Alanine aminotransferase, LDH: Lactate dehydrogenase, Cr: Creatinine, RRT: Renal replacement therapy, Hct: Hematocrit

be performed several times each day until stabilized. A urinary bladder catheter should be placed upon admission for close monitoring of urine output. Early recognition, evaluation, and treatment of compartment syndrome reduce the risk of crush syndrome and limb loss.[14] The need for amputations varies depending on delays in extrication, associated injuries, and local resources. Once AKI is established, aggressive IV fluid resuscitation is no longer appropriate. Hemodialysis is initiated for the usual indications of volume overload, hyperkalemia, severe acidemia, and uremia. IV fluids that had been started previously were continued in all patients, and clinical examination and laboratory studies were performed several times each day. In this study, fasciotomy was performed in 7 patients and amputation was performed in 3 patients. Five of the patients who underwent fasciotomy did not require amputation. Our data support that timely fasciotomy reduces the need for amputation. Also, clinical well-being was determined after amputation. AKI was detected in 9 patients, hemodialysis was performed in 7 patients due to anuria and persistent hyperkalemia.

In a limited number of pediatric CS studies, no association was found between the development of CS and age.[7] In addition, few of these studies examined the relationship between age and the need for RRT. Since only patients with CS were evaluated in our study, the relationship between age and CS development could not be examined. However, the relationship between age and RRT requirement was examined in our study. In this study, the mean age of patients who needed RRT was significantly higher. Also, a significant correlation was found between age and the need for RRT (r=0.839, p=0.001). This condition suggested that the injured muscle mass may have increased with increasing age.

Extrication time is strongly associated with earthquake-related mortality. A limited number of survivors may be extricated between 48 hours and 14 days after the event later.[15] It has been stated that widespread muscle injuries can be experienced also children who have been under the rubble only briefly.[9,16,17] Dönmez et al.[6] reported that the mean the time spent buried under rubble was 17.9±5.1 hours. They also reported that despite no significant correlation being observed between the time trapped under rubble and serum K, CK, AST, and LDH levels. Similarly, no significant correlation was found between the duration of being under rubble and F, CK, AST and LDH in our study. Iskit et al.[7] reported that

the mean time spent under rubble was 35.44±13.34 and no correlation was found between the time spent under rubble and AKI. In this study, the time spent under rubble and the mean admission time were 18.5±12.8 and 29.9±39.2 hours, respectively. AKI was detected in 9 patients. The mean time under rubble (21.3 h) and admission time to the intensive care unit (34.5 h) were significantly higher in these patients. We think that the detection of AKI in almost all patients diagnosed with CS, who experienced very long stays under the rubble, may be affected by the correlation identified in their study. Although the mean time to stay under rubble in our study was very short compared to theirs, AKI was detected in most of our patients (82%) supports the importance of early rescue.

It is expected that some clinical and laboratory features in patients will be adversely affected as the duration of stay under the rubble is prolonged. In addition, the time for admission to PICU may also have an effect on these parameters. For these reasons, correlation analysis was performed between the duration of stay under the rubble, the time for admission to PICU, and various parameters (Table 5). There was a significant increase in creatinine (r=0.702, p=0.024), d-dimer levels (r=0.784, p=0.012), and the need for fasciotomy (r=0.647, p=0.043), with prolonged time under the rubble. In addition, it was observed that there was a significant decrease in ionized calcium and albumin levels as the duration increased. In our study, similar to Dönmez et al.[6], no significant correlation was found between biochemical indicators of muscle damage and the duration of stay under the rubble. This suggested that the muscle damage started early in patients and did not increase in correlation with the duration beyond a certain point. Previous studies support this as well.[16,17] In our study, the significant correlation of D-dimer, which is an indicator of DIC, and creatinine, which is an indicator of AKI, with time under rubble revealed the importance of time under rubble. The most striking and overlooked finding was the relationship between ionized calcium and the time spent under rubble. Ionized calcium is a vital electrolyte that is not routinely checked. No correlation was found between the PICU admission time and any parameter. This may be related to the initiation of treatment prior to our involvement.

There are different reports in the literature regarding the relationship between the number of injured extremities and compartment syndrome complications. Oda et al.[9] reported that the peak serum CK level and incidence of AKI increased as the number of injured extremities increased. Dönmez et al.[6] reported that AKI was observed in only 14.3% of children with single extremity injury and 85.7% of children with multiple extremity injuries, and the peak serum CK level was higher in children with multiple extremity injuries, but this difference was not found significant. Iskit et al.[7]. reported that there was no correlation between the number of extremities with crush injury (CI) and the incidence of AKI. They also reported that serum blood urea nitrogen, creatinine, and potassium levels did not differ when CI involved more than one extremity. Although many parameters were poor in patients with multiple extremity injuries in our study, the differences were not significant (Table 2).

The most important and preventable prognostic complication in the CS is the development of AKI.[6,7,13,16,18] Efforts to prevent and treat AKI primarily focus on fluid replacements. RRT should be applied in unresponsive cases. We could not find literature information on clinical and laboratory features that would predict the need for RRT in pediatric patients with CS. For this reason, we examined the relationship between the clinical and laboratory characteristics of our patients at the time of admission and the need for RRT (Table 3). A significant relationship was found between the presence of dark urine, older age, high PRISM score, elevated blood uric acid and lactate levels, and RRT requirement. Although the mean CK, LDH, and D-dimer levels were higher in the RRT group, this difference was statistically borderline. Thus, it was concluded that patients with the characteristics listed at the time of admission may need RRT during follow-up. We think that this data make a significant contribution to the literature.

Study Limitations

There are some limitations of our study. The main limitation is that single center data has been presented, and the study includes a small number of cases. Since the number of patients is small, we think that the relationship between many laboratory parameters and the need for RRT remains statistically borderline. Since patients who did not develop CS were excluded from the study, no comment could be made on earthquake-related pediatric trauma. This is another limitation of this study.

Conclusion

Our results show that survival is possible in CS cases with effective and timely treatment approaches. We found that as the time spent under rubble increased, blood D-dimer and creatinine levels increased, and iCa and albumin levels decreased. At admission, presence of dark urine, high prism score, high blood uric acid and lactate levels were associated with the need for RRT. Additionally, mortality was found to be higher in patients with high d-dimer and lactate levels at the time of admission. We think that our results should be confirmed with a larger number of patients.

Ethics

Ethics Committee Approval: Ethical approval was obtained from Gaziantep University Clinic Research Ethics Committee (decision no: 2023/305, date: 04.10.2023).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.B., M.A.K., B.D.K., Concept: M.B., Ç.K., Design: M.B., Ç.K., M.A.K., B.D.K., Data Collection or Processing: E.K., M.D., Analysis or Interpretation: Ç.K., M.A.K., B.D.K., Literature Search: Ç.K., Writing: Ç.K.

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