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Clinical Features & Early Treatment Outcomes Of Children With Crush Syndrome After Kahramanmaraş Earthquake

Kahramanmaraş Deprem Sonrası Crush Sendromlu Çocukların Klinik Özellikleri Ve Erken Tedavi Sonuçları

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Abstract

Objective: Extensive muscle crush injury that results in crush syndrome is often fatal if not treated promptly and vigorously. Although cases of Crush syndrome experienced by adults were frequently published in the previous literature, data on Crush syndrome in children are limited. In this study, we aimed to elucidate the clinical and laboratory findings of children with Crush syndromewho applied to our institution after the earthquake.
Methods: Thirty-eight children with crush syndrome who applied to our institution after the earthquake disaster have been enrolled in this retrospective analysis. Demographic, clinical, and laboratory characteristics and early outcomes of children with crush wounds have been evaluated retrospectively. All children with crush wounds have been included in the analysis. Age, sex, height, and weight of the patient, admission and follow-up laboratory parameters, presence of comorbid diseases, and transcutaneous oximetry measurement results have been obtained from the hospital's electronic database.
Results: The stay under wreckage ranged from 4 to 160 hours, averaging 30 hours. The mean length of hospital stay was 13days, and the length of intensive care unit stay was seven days. There was a statistically significant difference between the initial and final measurements of WBC, PLT, CRP, glucose, BUN, creatinine, AST, ALT, LDH, uric acid, CK, and albumin values ($p<0.05$). Children with multiple extremity involvementhad significantly elevated initiallaboratory measurements, while those with single extremity involvement presented higher values in the final measurements ($p<0.05$).
Conclusion: The high creatine kinase levelsmight indicate the severity of muscle damage in Crush syndrome. Elevated creatine kinase could be used to indicatemortality in these patients. Early assessment of compartment pressure can eliminate the risk of amputation. Rapid diagnosis and aggressive fluid resuscitation in the emergency department can prevent acute kidney injury or failure.

Keywords: Crush Syndrome, Extremity İnvolvement, Fasciotomy, Debridement, Earthquake.

Özet

Amaç: Crush sendromuyla sonuçlanan yaygın kas ezilme yaralanması, hızlı ve kuvvetli bir şekilde tedavi edilmezse genellikle ölümcüldür. Önceki literatürde yetişkinlerin yaşadığı Crush sendromu vakaları sıklıkla yayınlanmış olsa da, çocuklarda Crush sendromuna ilişkin veriler sınırlıdır. Bu çalışmada deprem sonrası kurumumuza başvuran Crush sendromlu çocukların klinik ve laboratuvar bulgularının aydınlatılmasını amaçladık.
Yöntem: Bu retrospektif çalışmaya deprem felaketi sonrası kurumumuza başvuran ezilme sendromlu 38 çocuk dahil edildi. Ezilme yarası olan çocukların demografik, klinik ve laboratuvar özellikleri ile erken dönem sonuçları retrospektif olarak değerlendirildi. Ezilme yarası olan tüm çocuklar analize dahil edilmiştir. Hastanın yaşı, cinsiyeti, boyu, kilosu, başvuru ve takip laboratuvar parametreleri, eşlik eden hastalık varlığı ve transkutan oksimetre ölçüm sonuçları hastanenin elektronik veri tabanından elde edildi.

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Bulgular: Enkaz altında kalma süresi 4 ile 160 saat arasında değişerek ortalama 30 saat olmuştur. Ortalama hastanede kalış süresi 13 gün, yoğun bakımda kalış süresi ise yedi gündü. WBC, PLT, CRP, glukoz, BUN, kreatinin, AST, ALT, LDH, ürik asit, CK ve albümin değerlerinin başlangıç ve son ölçümleri arasında istatistiksel olarak anlamlı fark vardı ($p<0,05$). Birden fazla ekstremite tutulumu olan çocuklarda ilk laboratuvar ölçümlerinde anlamlı olarak yüksek bulunurken, tek ekstremite tutulumu olanlarda son ölçümlerde daha yüksek değerler saptandı ($p<0.05$).
Sonuç: Yüksek kreatin kinaz seviyeleri, Crush sendromunda kas hasarının şiddetini gösterebilir. Yüksek kreatin kinaz bu hastalarda mortaliteyi belirtmek için kullanılabilir. Bölme basıncının erken değerlendirilmesi amputasyon riskini ortadan kaldırabilir. Acil serviste hızlı tanı ve agresif sıvı resüsitasyonu, akut böbrek hasarını veya yetmezliğini önleyebilir.

Anahtar Kelimeler: Crush Sendromu, Ekstremite Tutulumu, Fasyotomi, Debridman, Deprem.

INTRODUCTION

Crush syndrome is a form of traumatic rhabdomyolysis characterized by systemic involvement that occurs after prolonged continuous pressure. Extensive muscle crush injury that results in crush syndrome is often fatal if not treated promptly and vigorously (1).

Damages appear after prolonged pressure is applied to a muscle group. Pressure causes muscle necrosis, and during revascularization, calcium, sodium, and water diffusion into damaged muscle cells, accompanied by loss of potassium, phosphate, lactic acid, myoglobin, and creatinine kinase. These changes can lead to hyperkalemia, acidosis, acute renal failure, and hypovolemic shock (2). These patients may also develop serious local or systemic infections complicated by disseminated intravascular coagulation (DIC). Myoglobin causes kidney damage through mechanisms that are not fully defined. If renal failure develops, hemodialysis is started (3).

Indications for fasciotomy are the absence of a distal pulse or open lesions. When a fasciotomy is performed, the entire necrotic muscle must be radically removed (4). Crush syndrome is usually encountered in war zones, mining disasters, earthquakes, and occupational and traffic accidents. The first cases of Crush syndrome were identified during the Sicilian earthquake in Messina in 1909. Also 1940, the relationship between crush syndrome and myoglobinuric acute renal failure was reported (5). Difficulties with communication and transportation during a disaster often preclude early rescue and therapeutic interventions. Early extraction and intravenous fluid administration prevent failure (6).

A violent earthquake happened at4:17 a.m. and 1:24 p.m. on February 6, 2023, in southeastern and northwest regions of Turkey for 60 and 45 seconds, respectively, and thousands of sleeping families have buried graves. The earthquake's epicenter was Kahramanmaras,recorded on the Richter scale as 7.7 and 7.6, respectively.

Although cases of Crush syndrome experienced by adults were frequently published in the previous literature, data on Crush syndrome in children are limited.

Within the scope of this research, we aimed to elucidatethe relationshipbetween creatinine kinase, fasciotomy, and amputation rate. Additionally, we have investigated whether creatinine kinase is affected by the duration of stay in wreckageafter the earthquake.

METHOD

Thirty-eight children with crush syndrome who applied to our institution after the earthquake disaster have been enrolled in this retrospective analysis. All procedures were followed in

accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Ethics committee approval has been granted from our institution at 03/03/2023 with protocol number 332. As this was retrospective research, no informed consent was obtained from participants or their legal representatives.

Demographic, clinical, and laboratory characteristics and early outcomes of children with crush wounds have been evaluated retrospectively. All children with crush wounds have been included in the analysis. Age, sex, height, and weight of the patient, admission and follow-up laboratory parameters, presence of comorbid diseases, and transcutaneous oximetry measurement results have been obtained from the hospital's electronic database.

Statistical Analysis

The patient data collected within the scope of the study were published in the IBM Statistical Package for the Social Sciences (SPSS) for Windows 23.0 (IBM Corp. Harmonik. NY) was analyzed with the package program. Frequency and percentage were given as the categorical data's mean, standard deviation, median, minimum, and maximum descriptive values. "Independent Sample T Test" or "Mann Whitney U Test" for the two groups in the intergroup comparisons, "Paired Sample T-Test" or "Wilcoxon test" for the evaluation ofthe difference between the first and last measurement values, "Chi-square or Fisher's Exact Test" for the evaluation of categorical variables Test" was used. The results were considered statistically significant when the p-value was less than 0.05.

RESULTS

A total of 38 children have been enrolled within the scope of this research. The gender distribution could be elaborated as follows: 52.6% (n=20) were female, and 47.4% (n=18) were male. The mean age of the patients was ten years rangingbetween 1 to 17 years. The stay under wreckage ranged from 4 to 160 hours, with an average time of 30 hours. The mean length of hospital stay was 13 days(minimum two days, maximum 35 days),and the length of intensive care unit stay was seven days(minimum 0days, maximum 28 days).Intubation and mechanical ventilation have been performed on one patient each, respectively.The injured extremity involvement could be elaborated as the bottom left (n=27), lower right(n=23), upper left (n=9), and upper right (n=7).Fasciotomy has been performed on different areas: bottom left (n=12), lower right (n=9), and upper left (n=5).Amputation has been performed on eight patients, and debridement on 17. An infection has been observed in 38 children, and sepsis in only one child. The distribution of baseline demographics and clinical features of the patients are elaborated in Table 1.

The distribution of the first and last laboratory measurements of the patients is given in Table 2. When the table is examined, it was determined that there was a statistically significant difference between the initial and final measurements of WBC, PLT, CRP, Glucose, BUN, creatinine, AST, ALT, LDH, uric acid, CK, and albumin values ($p<0.05$).The median CK level at admission was 18.1U/L(range 1.8 – 330U/L) and 208 U/L(range 1.5 – 919 U/L) at the final measurement,and this difference was statistically significant ($p<0.001$). On the contrary, CK–MB values at admission and final follow-up did not reach significance (97.2 U/L range 19.6 – 466U/L versus 77.5 U/L range 18.5 – 432 U/L respectively, $p<0.070$).

Table 1. Distribution of Demographic and Clinical Findings of Patients

Variables (N=38)	n (%)	Average ± SD	Median (Min-Max)
Age (years)		10±4.4	9 (1-17.4)
Height (cm)		132.6±24.4	135 (72-172)
Weight (kg)		37±15.5	32 (12-64)
Gender			
Female	20 (52.6)		
Male	18 (47.4)		
Wreckageperiod (hours)		30.3±37.4	13 (4-160)
Protein in Urine		135.7±135.4	68 (68-338.7)
Hyperbaric O_2 Treatment	38 (100)		
Hospitalization (days)		13.1±8.2	11 (2-35)
ICU stay (days)		7±6.3	6.7 (0.2-27.7)
Intubation	1 (2.6)		
Mechanical Ventilation	1 (2.6)		
Sepsis	1 (2.6)		
Injured extremity			
Upper right	7 (18.4)		
Upper left	9 (23.7)		
Lower right	23 (60.5)		
Bottom left	27 (71.1)		
Fasciotomy	17 (44.7)		
Anatomical region			
Upper left	5 (29.4)		
Lower right	9 (52.9)		
Bottom left	12 (70.6)		
Debridement	17 (44.7)		
Amputation	8 (21.1)		
Amputation direction			
Upper left	2 (25)		
lower right	6 (75)		
Bottom left	7 (87.5)		
Infection	38 (100)		
Blood Transfusion	2 (9.1)		
Wound KX	6 (66.7)		

The distribution of demographic characteristics according to the involvement of one or more extremities is given in Table 3. When the table was examined, there was no statistically significant difference between the two groups in all demographic and clinical findings.

Table 2. Distribution of Laboratory Measurements of Patients

Variables	First Measurement		Final Measurement		p-value
	Average ± SD	Median (Min-Max)	Average ± SD	Median (Min-Max)	
WBC	**14.1±6.5**	**11.8 (5.6-34.9)**	**11.4±4.9**	**10.7 (4.7-27.5)**	**0.028**
Hemoglobin	12.1±5.4	10.4 (7.3-36.7)	12.5±12	9.4 (6.9-79)	0.790
HCT	36±11.2	33.9 (22.7-82.2)	32.8±13.6	30.1 (5.4-82.2)	0.150
PLT	**309.3±127.9**	**313 (91-593)**	**431.8±189.8**	**436 (59-915)**	**<0.001**
CRP	**65.3±54.6**	**41.9 (2-160.9)**	**23±41.1**	**4.1 (2-203.8)**	**<0.001**
PT	65.3±23.8	73 (7-98)	67±22	72.5 (13-98)	0.645
APTT	33.4±18.6	28.6 (17.8-102.1)	32.4±16.3	29.5 (16.1-96.3)	0.778
INR	1.3±0.3	1.2 (1-2.5)	1.2±0.4	1.2 (1-3.6)	0.760
Fibrinogen	358.7±147.1	369 (24-671)	304.2±130.3	316 (22-546)	0.068
Glucose	**143.7±90.2**	**113.5 (74-446)**	**106.5±47.3**	**96.5 (65-324)**	**0.009**
BUN	**82.8±84**	**40 (4-343)**	**29.7±15.8**	**26 (10-90)**	**<0.001**
Creatinine	**1±1.3**	**0.5 (0.3-5)**	**0.6±0.5**	**0.4 (0.1-2.8)**	**0.015**
AST	**594.4±636.3**	**336 (31-3004)**	**93.6±177.2**	**33.3 (8-891.5)**	**<0.001**
ALT	**332.4±475**	**240 (29-2986)**	**68±94.8**	**33.5 (9-536)**	**0.002**
LDH	**1765.1±2502.1**	**1022 (22.1-10023)**	**475.8±378**	**393.5 (44-2201)**	**0.001**
Uric Acid	**6.3±5.3**	**4.1 (1.8-20)**	**3±1.3**	**2.8 (0.9-7.8)**	**<0.001**
CK	**45.2±65.3**	**18.1 (1.8-330)**	**258.8±249.6**	**208 (1.5-919)**	**<0.001**
CK-MB	137.1±127.2	97.2 (19.6-466)	119.7±118	77.5 (18.5-432)	0.070
Albumin	**24.9±7.1**	**25 (13-44)**	**31.4±9.5**	**34 (6-49.1)**	**<0.001**
Na	134.9±8.2	135 (121-162)	134.3±16.6	137 (37-144)	0.827
K	4.6±1.3	4.2 (3.1-9.2)	4.7±1.5	4.4 (3.2-9.5)	0.802
Ca	7.9±1	7.9 (5.3-10.1)	8.3±1.8	8.8 (1.8-10.5)	0.274
Fosfor	4.8±2.5	4.5 (1.4-12.1)	4.5±1.2	4.4 (1.4-6.1)	0.340

The distribution of laboratory measurements according to the involvement of one or more extremities is given in Table 4. When the table was examined, it was seen that there was a statistically significant difference between the two groups in the baseline WBC, uric acid, potassium values, and final WBC, albumin, and calcium measurements ($p<0.05$).Children with multiple extremity involvementhad significantly higher initiallaboratory measurement levels, while this was vice versain those with single extremity involvement, as they presented higher values in the final measurements.

Table 3. Distribution of Demographic and Clinical Findings of Patients with Single and MultipleExtremity Involvement

Variables	Single extremity (n=14)			Multiple extremity(n=24)			p-value
	n (%)	Average± HR	Median (Min-Max)	n (%)	Average± HR	Median (Min-Max)	
Age (years)		10.8±5.6	10.4 (2-17)		9.9±3.5	9 (1-17.4)	0.614
Height (cm)		133.9±30	133.5 (76-172)		131.8±21.1	135 (72-162)	0.794
Weight (kg)		38.3±17.9	34 (12-61)		36.3±14.3	32 (14-64)	0.702
Gender							0.151
Female	10 (71.4)			10 (41.7)			
Male	4 (28.6)			14 (58.3)			
Time spent in the wreckage (hours)		28.2±39.8	14 (4.5-160)		31.5±36.7	11.5 (4-128)	0.798
Hospitalization (days)		13.2±9.8	14 (2-35)		13±7.4	11 (2-35)	0.925
ICU hospitalization (days)		7.3±7.4	6.4 (0.2-27.7)		6.8±5.8	6.7 (0.8-27.7)	0.855
Intubation	0 (0)			1 (4.2)			1.000
Mechanical Ventilation	0 (0)			1 (4.2)			1.000
Fasciotomy	7 (50)			10 (41.7)			0.873
Debridement	7 (50)			10 (41.7)			0.873
Amputation	2 (14.3)			6 (25)			0.684
Blood transfusion	0 (0)			2 (13.3)			1.000
Wound K-X	2 (66.7)			4 (66.7)			1.000

Table 4. Distribution of Laboratory Measurements of Patients with Single and MultipleExtremity Involvement

Measurements	Single extremity (n=14)		Multiple-extremity (n=24)		p-value
	Average±HR	Median (Min-Max)	Average±HR	Median (Min-Max)	
First-WBC	**10.7±3.9**	**10.4 (5.6-21.8)**	**16.2±7**	**13.8 (8.6-34.9)**	**0.004**
Final-WBC	**8.8±2.6**	**9.2 (4.7-13.4)**	**12.9±5.4**	**11.4 (6.7-27.5)**	**0.011**
First-Hb	12.9±8.1	10.2 (7.8-36.7)	11.6±3.1	11 (7.3-20.4)	0.582
Final-Hb	12.6±6.9	9.7 (7.9-30.5)	12.5±14.3	9.3 (6.9-79)	0.985
First-HCT	34.2±7.5	34.1 (23.9-50.2)	37.1±13	33.4 (22.7-82.2)	0.453
Final Hct	29.9±8.1	30.1 (5.4-39.1)	34.5±15.9	29.2 (22.9-82.2)	0.318
First-Plt	295.9±113.7	315.5 (91-469)	317.1±137.2	306.5 (107-593)	0.628
Final Plt	474.9±121.4	478 (258-707)	406.7±218.7	361.5 (59-915)	0.291
First-CRP	49.6±53.5	20.1 (6.5-153.7)	73.7±54.4	70.8 (2-160.9)	0.204
Final-CRP	10.3±25.4	2 (2-93.9)	29.9±46.5	12.3 (2-203.8)	0.170
First-PT	69.7±25.2	80.5 (12-92)	63.1±23.4	62.5 (7-98)	0.446
Final-PT	72.8±22.4	78.5 (13-91)	64.1±21.6	70.5 (14.2-98)	0.273
First-APTT	28.2±5.8	27.1 (23-45)	36±22.1	29 (17.8-102.1)	0.114
Final APTT	27.6±4.5	26.5 (21.8-39.4)	34.8±19.4	30.1 (16.1-96.3)	0.216
First-INR	1.3±0.4	1.1 (1.1-2.5)	1.2±0.2	1.2 (1-1.9)	0.652
Final-INR	1.1±0.1	1.1 (1-1.4)	1.3±0.5	1.2 (1-3.6)	0.370
First-Fibrinogen	313.4±207.1	385 (24-563)	372.8±128.6	366.5 (219-671)	0.445
Final-Fibrinogen	250±165.6	274 (22-462)	321.1±118.4	328 (140-546)	0.298
First-Glucose	157.6±120.4	106 (75-446)	135.6±68.7	120 (74-408)	0.540
Final-Glucose	110±62	96.5 (84-324)	104.4±37.7	97.5 (65-245)	0.731
First-BUN	59.7±67.5	30 (4-218)	95.3±90.6	52.5 (10-343)	0.223
Final-BUN	26.5±8.9	26 (13-42)	31.4±18.4	29 (10-90)	0.369
First-Creatine	0.9±0.9	0.6 (0.3-3.1)	1.1±1.5	0.5 (0.3-5)	0.679
Final-Creatine	0.5±0.2	0.5 (0.1-0.9)	0.6±0.6	0.4 (0.3-2.8)	0.682
First-AST	378.2±395.6	255 (31-1527)	720.5±719.6	452.5 (33-3004)	0.111
Final-AST	45.2±34.2	32.5 (16-140)	121.8±218.1	45 (8-891.5)	0.104
First-ALT	207±152	219.5 (29-562)	405.6±578.5	298 (76-2986)	0.218
End-ALT	45.8±52.8	32 (9-185)	80.9±111.4	36.7 (9-536)	0.277
First-LDH	1086.8±918.9	881 (132-3025)	2160.7±3025.1	1071 (22.1-10023)	0.117
Final-LDH	323.2±140.3	295 (44-530)	564.8±443	466 (46.3-2201)	0.056
First-Uric-Acid	**4±3.1**	**3.2 (1.8-13.4)**	**7.6±5.9**	**5.6 (1.9-20)**	**0.018**
Final-Uric-Acid	3.1±0.9	2.9 (1.6-5.2)	2.9±1.6	2.8 (0.9-7.8)	0.736
First-CK	46.8±86.4	13.4 (1.8-330)	44.2±51.4	18.1 (3.2-167.2)	0.909
Final-CK	216.8±183.2	147 (1.5-629)	283.3±282.1	217 (1.5-919)	0.435
First-CK-Mb	69.6±55.1	50.4 (26.9-150.4)	164.1±139.8	147.2 (19.6-466)	0.222
Final- CK-Mb	76.1±52.6	70.1 (22.1-142.1)	137.1±134.2	98 (18.5-432)	0.404
First-Albumin	25.1±6	25.5 (13-34)	24.7±7.7	24 (13.8-44)	0.884
Final -Albumin	**35.8±8.1**	**36 (13-49.1)**	**28.8±9.4**	**28.6 (6-44)**	**0.026**
First-Na	137±5.7	136.5 (128-150)	133.8±9.3	134 (121-162)	0.246
Final -Na	137.9±2.7	138.5 (133-142)	132.3±20.6	137 (37-144)	0.321
First-K	**4.1±0.5**	**4.1 (3.4-5.2)**	**4.9±1.5**	**4.8 (3.1-9.2)**	**0.023**
Final -K	4.4±0.4	4.5 (3.9-5)	4.8±1.8	4.3 (3.2-9.5)	0.314
First-Ca	8.3±0.9	8.4 (6.7-9.9)	7.7±1	7.4 (5.3-10.1)	0.055
Final-Ca	**9.1±0.4**	**9.2 (8.1-10)**	**7.8±2.1**	**8.5 (1.8-10.5)**	**0.007**
First-Phosphorus	4.5±1.2	4.5 (2.6-6.5)	5±3	4.2 (1.4-12.1)	0.483
Final-Phosphorus	4.8±0.8	4.7 (3.1-6.1)	4.3±1.4	4.3 (1.4-6.1)	0.245

DISCUSSION

Trauma types seen during earthquakes differ according to the infrastructure characteristics of the countries. For example, when all hospital admissions were reviewed during the 2005 Battagram, Pakistan Earthquake, it was reported that superficial traumas such as laceration and contusion were the most common, followed by orthopedic extremity trauma, head trauma, thoracic trauma, and closed abdomen trauma (7). In the 2011 Van, Turkey Earthquake, 95% of the disaster victims were brought to hospitals with soft tissue trauma, followed by multiple extremity fractures and compartment syndrome (8). In the Southern Italy Earthquake, approximately half of the disaster victims were injured in more than one part of the body; here, too, the most frequently reported injury type was laceration, followed by contusions, fractures, and cuts (9). One of the most detailed documentation on earthquake traumas was made after the Hanshin-Awaji Earthquake in Japan. In the first 15 days after the disaster, earthquake-related traumas were found in 2718 out of 6107 patients in the examination admission to 95 hospitals. Extremity, spine, pelvis, and other fractures were recorded most frequently in this patient group. Soft tissue traumas, including contusions, lacerations, and cuts, occurred in 35.1%; crush syndrome developed in 372 patients, and peripheral nerve damage was detected in 131 patients (10). When extra-extremity traumas were examined in patients with crush syndrome in the Kobe Earthquake and the Marmara Earthquake in our country, thoracic and abdominal traumas with a high mortality rate were followed by head and pelvis traumas (11). In our study, the injured extremity involvement could be elaborated as the bottom left (n=27), lower right (n=23), upper left (n=9), and upper right (n=7).Fasciotomy has been performed on different areas: bottom left (n=12), lower right (n=9), and upper left (n=5).

Rhabdomyolysis occurs due to the stretching of the muscle sarcolemma due to pressure. When the sarcolemma is stretched, its permeability increases, and sodium, calcium, and water enter the cell. When the intracellular calcium level increases, proteolytic enzymes are activated,destroying the membrane (12). As a result, potassium, aldolase, phosphate, myoglobin, creatine kinase, lactate dehydrogenase, AST, ALT, and uric acid penetrate the bloodstream. These substances, whose levels rise in the blood, are responsible for toxic and fatal complications. Another mechanism that triggers rhabdomyolysis is ischemia. Ischemia occurs in skeletal muscle within 30 minutes, and edema and lysosome degranulation occur. Free radicals released in ischemia-reperfusion damage that develops during ischemia recovery also affect the pathogenesis of rhabdomyolysis (13). Increased intra-compartmental pressure due to trauma or edema disrupts the circulation in the muscle tissue. Impairment of blood supply causes ischemia, and edema tissue ischemia causes necrosis. ARF can be seen due to acidosis and myoglobinuria resulting from muscle tissue destruction (12 – 14).

The enzyme creatine kinase (CK) is found in striated muscles and is released into the circulation in case of muscle damage. Creatine kinase has two subtypes, CK–MM and CK–MB. In rhabdomyolysis, high concentrations of CK–MM enter the circulation. Serum CK concentration, mainly the CK–MM subtype, is the most sensitive indicator of muscle damage. The serum CK level begins to rise approximately 2 – 12 hours after muscle injury, peaks within 24 – 72 hours, then declines at a steady rate of 39% of the previous day's valueand returns to its normal value in 3 – 5days(15).Anion gap metabolic acidosis is increased s due to organic acids released from necrotic muscle cells, accumulated organic acids due to acute kidney injury (AKI), and lactic acid. Rhabdomyolysis usually leads to a faster increase in plasma creatinine than other causes of AKI. The BUN/creatinine ratio is often low in this patient group. Normal serum creatine kinase values are 25 – 175 U/L, but in cases with Crush syndrome, it usually rises above 15.000 IU/L. The peak value of creatine kinase can reach

100.000 IU/L. High creatine kinase values (especially CK>75.000 IU/L) are associated with acute kidney failure and mortality. The half-life of creatine kinase is 1.5 days, and the half-life of myoglobin is 3 hours. Also, creatine kinase is not removed by kidney or dialysis. Therefore, creatine kinase monitoring is more reliable than myoglobin monitoring for the treatment and prognosis of Crush syndrome (16). CK activity above 5.000 IU/L indicates severe muscle damage and is a potential indicator of kidney failure that may develop. Clinically, rhabdomyolysis can vary from asymptomatic to life-threatening clinical conditions such as cardiac arrhythmias, acute kidney injury, and disseminated intravascular coagulation(17). In our study, the median CK level at admission was 18.1U/L(range 1.8 – 330 U/L) and 208 U/L(range 1.5 – 919 U/L) at the final measurement, and this difference was statistically significant ($p<0.001$). On the contrary, CK–MB values at admission and final follow-up did not reach significance (97.2 U/L range 19.6 – 466 U/L versus 77.5 U/L range 18.5 – 432 U/L respectively, $p<0.070$).

The prominent local finding in patients is compartment syndrome. Other local findings are elaborated as 6P: pain, pressure, paresthesia, pulselessness, paresis, and pallor. Systemic findings differ according to the affected organ. Systemic findings are hypovolemic shock, hypotension, AKF, arrhythmia, heart failure, respiratory failure, infection, and sepsis. Oliguria or anuria may be seen in patients due to AKF(19).

Fasciotomy is a surgical incision in the fascia of the injured muscle to reduce intracompartmental pressure. There is no consensus on the indications for fasciotomy. Routinely performed fasciotomies in the early period can reduce the risk of necrotic muscle mass, the severity of kidney failure, peripheral neuropathy, and ischemic contracture, but they increase the risk of infection. Fasciotomy is a major risk factor for sepsis and should not be performed unless there are clear indications(20). Sepsis developed in 25% of patients who underwent fasciotomy in the Marmara Earthquake (21). During the Van Earthquake, 5 (23.8%) of 21 victims who underwent fasciotomy in Van Training and Research Hospital received treatment for sepsis (22). Fasciotomy should be considered in selected patients at risk of ischemia and gangrene, whose distal pulse cannot be obtained, whose intracompartmental pressure exceeds 50 mmHg, or whose pressure values between 30 and 50 mmHg do not tend to decrease for more than 6 hours.Guidelines recommend that amputation be limited to situations where a limb is unrecoverable or where injuries to the limb cause sepsis, systemic inflammation, or uncontrollable bleeding. İskit et al. reported that they performed fasciotomy in nine extremities of six children with compartment syndrome, who were admitted late after the third day, in whom distal pulses could not be detected. Still, they did not perform an amputation on patients (23). Donmez et al. reported performing fasciotomy in 15 of 20 pediatric patients and amputation in six extremities of four children(24).In our study, infection was observed in 38 children, and sepsis in only one child. Amputation has been performed on eight patients, and debridement on 17.

In the 1999 Marmara earthquake, child mortality was low compared to the general affected population. Only 18.7% of the population in the earthquake area were younger than ten years old, but only 1.9% of crush-related AKI patients were that age. This suggests that children may have died at the earthquake scene or been less affected by rhabdomyolysis complications due to their low body surface area (25). In a study by Jacquet et al., who systematically reviewed the literature on earthquake-related injuries in the pediatric population from 1950 to 2012 to provide recommendations for improving the reporting and classification of pediatric injuries in disasters, crush injuries were reported between 6.3% and 18.7% (26). It has been shown that the duration of being under the wreckage for children exposed to crush syndrome after the Marmara earthquake was also significantly longer than adults (23, 24). This finding

suggests that children are protected from trauma in narrow ranges. During the Guatemala earthquake, trauma risk and mortality were inversely proportional to age, except for very young children, probably because they slept with their parents (27). In the Iran-Bam earthquake, the percentage of crushed children and youth younger than 15 was significantly lower than the affected adult population in the same region (28). Less trauma, fractures, and chest injuries were recorded in children younger than ten in the China earthquake (29). Similar observations were also reported after the Japan Kobe earthquake (10).

Dönmez et al. stated that crushing syndrome of a large skeletal muscle mass, sensory and motor disturbances in the extremities, myoglobinuria and/or hematuria, and serum creatine kinase levels >1.000 U/L as diagnostic criteria for crush syndrome in the children they followed after the 1999 Marmara earthquake (24). Iskit et al. reported that they considered children with myoglobinuria or AKI (the cases with serum creatinine levels above 1.2 mg/dl or oliguria were accepted as AKI) with crush injury as crush syndrome (23). Oda et al.published the incidence of AKI in children with one, two, and three extremity injuries as 50.5%, 74.5%, and 100%, respectively. In the same study, they indicated that they observed AKI only in 14.3% of children with one extremity injury and in 85.7% of children with multiple extremity injuries and that the number of affected extremities is an important factor in determining the severity of crush syndrome (30). In our study, intubation and mechanical ventilation were performed on one patient each, respectively. Regarding biomarkers and laboratory parameters, there was a statistically significant difference between the two groups in the baseline WBC, uric acid, potassium values, d final WBC, albumin, and calcium measurements ($p<0.05$).Children with multiple extremity involvementhad significantly higher initiallaboratory measurement levels, while this was vice versain those with single extremity involvement, as they presented higher values in the final measurements.

CONCLUSION

As earthquakes are unpredictable, it is necessary to be prepared. The high creatine kinase levelsmight indicate the severity of muscle damage in Crush syndrome. Elevated creatine kinase could be used to indicate in-hospital mortalityin these patients. Early assessment of compartment pressure can eliminate the risk of amputation. Rapid diagnosis and aggressive fluid resuscitation in the emergency department can prevent acute kidney injury or failure.

Ethical Declaration

All procedures were followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Ethics committee approval has been granted from our institution. As this was a retrospective research no informed consent has been obtained from participants.

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Abbreviations

AKF : Acute kidney failure
AKI : Acute kidney injury

ALT : Alanine transaminase
APTT : Activated partial thromboplastin time
AST : Aspartate transaminase
BUN : Blood urea nitrogen
CK : Creatine kinase
CRP : C – reactive protein
DIC : Disseminated intravascular coagulation
Hb : Hemoglobine
HCT : Hematocrite
ICU : Intensive care unit
INR : International normalized ratio
LDH : Lactate dehyrogenase
MV : Mechanical ventilation
PLT : Platelets
PT : Prothrombine time
SPSS : Statistical Package for the Social Sciences
WBC : White blood cells

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