İSTANBUL UNIVERSITY PRESS

Çocuk Dergisi - Journal of Child 2023;23(3):223-232
DOI: 10.26650/jchild.2023.1341364

RESEARCH ARTICLE / *ARAŞTIRMA MAKALESİ*

Management of an Earthquake in a Pediatric Intensive Care Unit

Çocuk Yoğun Bakım'da Deprem Yönetimi

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Citation/Atıf: Tanyildiz M, Ozden O, Ozbek L, Senkoylu K, Cakar A, Eren I, et al. Management of an earthquake in a pediatric intensive care unit. Çocuk Dergisi - Journal of Child 2023;23(3):223-232. https://doi.org/10.26650/jchild.2023.1341364

ABSTRACT

Objective: The 2023 Kahramanmaraş earthquake (7.8 magnitude) devastated Turkey, impacting approximately 14 million people and causing over 50,000 fatalities. This study suggests a pediatric protocol for managing earthquake victims in pediatric intensive care units (PICUs).
Materials and Methods: A retrospective, observational study was conducted. Within a week, 72 patients were followed and initially treated post-stabilization, per the treatment protocol and PICU organization. Of these, 58 were referred to tertiary PICUs in other cities. Thirteen patients treated at our regional PICU were reviewed.
Results: Thirteen patients were studied. Eight had severe crush injuries, including four extremities in one patient and both legs in another. The average time under debris was 14.8±13.8 h. Fasciotomy was performed on 46.1% (n=6) of patients. Debridement was needed in 61.5% (n=8), averaging 3.6±3.8 procedures per patient. Vacuum-assisted closure (VAC) was applied to 53.8% (n=7). Continuous renal replacement therapy (CRRT) was given to two of the three patients with acute kidney injury, while one received intermittent hemodialysis. Four patients underwent an average of 5.2±9.5 therapeutic plasma exchange (TPE) sessions. Hyperbaric oxygen therapy (HBOT) was administered for an average of 15.0±17.5 sessions to eight patients. No patient deaths occurred at our center.
Conclusion: Implementing a treatment protocol was crucial for disaster management. Specialized treatments, including daily TPE, frequent HBOT, anticoagulant and vasodilator therapies, and VAC, contributed to favorable outcomes for patients with severe crush syndrome.

Keywords: disaster, earthquake, pediatric intensive care management, protocol

ÖZ

Amaç: 2023 Kahramanmaraş depremi (7.8 büyüklüğünde) Turkiye'de yaklaşık 14 milyon insanın etkilendiği ve 50,000'den fazla kişinin yaşamını kaybettiği büyük bir felakete yol açmıştır. Bu çalışmada çocuk yoğun bakım ünitelerinde (ÇYBÜ) takip edilen pediatrik depremzede hastaları için bir tedavi protokolü oluşturulması amaçlanmıştır.
Metod: Bu çalışma gözlemsel, retrospektif bir çalışmadır. Deprem sonrası bölgesel yoğun bakıma destek amacıyla gidilmiş bir hafta içerisinde 72 hasta izlenmiş, bu hastaların 58'i başka üçüncü basamak merkezlere sevk edilmiş, 13 hasta hemodinamik ve metabolik stabilizasyonu sağlandıktan sonra kendi merkezimize sevk edilmiştir.
Sonuçlar: Çalışmaya 13 hasta alındı. Sekiz hastada ciddi ezilme hasarı mevcuttu bu hastaların birinin dört ekstremitesi, bir diğer hastanın her iki alt ekstremitesi etkilenmişti. Enkaz altında ortalama kalış süresi 14.8±13.8 saatti. Fasiyotomi hastaların % 46.1 (n=6)'ine uygulandı. Debridman hastaların % 61.5 (n=8)'ine uygulandı, hasta başına ortalama debridman sayısı 3.6±3.8 bulundu. Vakum yardımlı kapama (VAC) hastaların % 53.8 (n=7)'ine uygulandı. Akut böbrek hasarı üç hastada gelişti ve bu hastaların ikisine sürekli renal replasman tedavisi (CRRT) uygulandı, bir hastaya aralıklı hemodiyaliz tedavisi uygulandı. Dört hastaya ortalama 5.2±9.5 seans terapötik plazma değişimi (TPE) yapıldı. Hiperbarik oksijen tedavisi (HBOT) ortalama 15.0±17.5 seans olmak üzere sekiz hastaya uygulandı. Merkezimizde hiçbir hasta kaybedilmedi ve tüm hastalar taburcu edildi.
Sonuç olarak: Afet yönetiminde bir protokol oluşturmak oldukça önemlidir. Günlük TPE, sık aralıklarla uygulanan HBOT, antikoagülasyon ve VAC dahil olmak üzere uygulanan özel tedaviler ile ciddi ezilme sendromu olan hastalarda olumlu sonuçlar elde edilmiştir.

Anahtar Kelimeler: afet, çocuk yoğun bakım yönetimi, deprem, protokol

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Submitted/Başvuru: 11.07.2023 • **Accepted/Kabul:** 15.08.2023 • **Published Online/Online Yayın:** 24.10.2023

INTRODUCTION

The 2023 Pazarcik, Kahramanmaraş earthquake had a magnitude of 7.8, making it one of the largest disasters in Türkiye, affecting 11 provinces with a population of about 14 million people and resulting in more than 50,000 deaths (1,2). More than 500 children lost extremities due to amputation. In this article, we would like to share the invaluable lessons that Turkish healthcare professionals have learned the hard way with those whom we hope will never need it. A medical team from our hospital was sent to the regional PICU to support the treatment of pediatric earthquake victims. They followed many patients there, but some were admitted to our hospital after achieving adequate hemodynamics and metabolic balance for tertiary care.

The aim of this study was twofold. First, to provide healthcare professionals with a pediatric protocol on managing earthquake victims in PICU and sharing its outcomes. Second, to share the valuable knowledge that had been gained regarding how to organize the post-earthquake intensive care organization in the regional PICU and tertiary PICU, how resources will be allocated for different patient needs, and how to determine the appropriate transfer of patients between centers.

MATERIAL AND METHODS

This was an observational retrospective study. Our team arrived at the regional Pediatric Intensive Care Unit (PICU) 36 h after the Kahramanmaraş earthquake, and within a week, we followed up on 72 patients. We initiated their initial therapy and referred 58 patients to tertiary health institutions in other provinces. We performed a retrospective analysis of 13 patients who were referred to our center. This study was approved by the Koc University Committee on Human Research (approval number: 2023.133.IRB1.045). The written informed consent was obtained from the participants of the study or legally authorized parents or representatives. The treatment was provided according to a protocol that included regional PICU and tertiary PICU experiences and treatments.

1. Treatment Protocol

1.1. Hydration and diuresis

We initiated daily IV fluid therapy by administering 3500–4000 mL/m^2 of a 0.45% NaCl solution without potassium and with 50 mEq/L of $NaHCO_3$ added. We requested urine pH at least once daily to monitor urine alkalization and reduced alkalization if urine pH was above 8. During treatment, we monitored urine output and administered 20 ml/kg saline solution followed by 1–2 mg/kg furosemide in case of oliguria (urine output < 2 ml/kg/h). After administering furosemide, we monitored urine output for 1 h (furosemide stress test) and repeated the procedure once more if urine output was insufficient. We limited fluid consumption and prepared for emergency dialysis if urine output remained insufficient. We avoided hypervolemia during fluid therapy.

1.2. Hyperkalemia management

We initiated calcium gluconate treatment at a dose of 1 mEq/kg (maximum = 20 meq) to minimize cardiac side effects. We administered β-adrenergic therapy (inhaled salbutamol) and glucose/insulin solution (1 IU of crystalline insulin for every 4–5 g of glucose) to increase potassium entry into the cell. We used anti-potassium (polystyrene sulfonate calcium) salts in patients with an intact gastrointestinal tract. If the potassium level remained above 7 meq/L despite treatment, we carefully monitored it and initiated dialysis therapy if necessary.

1.3. Hemodialysis versus CRRT

For patients requiring dialysis, we preferred intermittent hemodialysis (HD) if they were hemodynamically stable. However, we preferred continuous renal replacement therapy (CRRT) in patients who were hemodynamically unstable, had a high risk of amputation, or had a serious crush injury.

1.4. Catheter procedure

We used a double-lumen hemodialysis catheter (Able, Covidien, Arrow) ranging from 9–11.5 F, depending on the patient's weight and height. We preferred the right jugular vein for catheterization, and a PICU specialist placed the catheter under ultrasound (US) guidance. We used the same catheter for both therapeutic plasma exchange (TPE) and CRRT in patients who needed it. During CRRT, we connected TPE to the set in tandem and did not insert an extra catheter.

1.5. Prime procedure

For pre-treatment priming of the CRRT and TPE set, we added 2500 U/L heparin to 1000 mL of 0.9% NaCl solution. We used half the dose of heparin in trauma patients. For patients weighing less than 10 kg or with unstable hemodynamics, we prepared the set with cross-matched packed red blood cells after priming with normal saline.

1.6. Hemodialysis method

In children with hemodynamically stable crush injuries and acute kidney injury (AKI), we preferred intermittent hemodialysis (IHD). We performed IHD using a volume-controlled HD machine (Fresenius 4008 S; Fresenius, Bad Homburg, Germany) and polysulfone membranes. The treatment dose for IHD was determined as 3–4 h per day with a blood flow rate of 4–8 mL/kg/min and a dialysate flow rate of 10–15 mL/kg/min (1.5–2 × blood flow rate). We used reverse osmosis distilled water and bicarbonate dialysate with volumetric ultrafiltration control (≤ 0.2 mL/kg/min or ≤ 5% by weight). We adjusted the potassium and sodium concentrations of the bicarbonate-containing dialysate solutions based on individual requirements. We recorded HD duration and total ultrafiltration volume at the end of each session, and we adjusted HD frequency and prescription based on changes in the patient's clinical and laboratory data. If the extracorporeal blood volume estimated by the dialyzer size and tubing exceeded 10% of the blood volume, we prepared circuit blood with 5% albumin or saline to prevent intradialytic hypotension.

1.7. CRRT method

We used CRRT with high-volume hemodiafiltration (CVVHDF) using the PrismaFlex device (Gambro, Lund, Sweden) and AN69 0.6–0.9 m^2 (Prismaflex M60–Prismaflex M100) membrane. We determined the dialysate rate using the 2000 mL/1.73 m^2/h calculation, and we determined replacement volumes using the same formula. We made a 1/3 pre-dilutional and 2/3 post-dilutional replacement capacity adjustment. If the patient weighed between 15 and 30 kg, we modified the blood flow rate to be 4–6 mL/kg/min. If the patient weighed more than 30 kg, we reduced the blood flow rate to 2–4 mL/kg/min.

1.8. Intensive care management in patients considering amputation

We used mangled extremity severity score (MESS) to estimate viability of a crushed extremity (3).

Anti-coagulation: A heparin infusion of 10 U/kg/h (maximum 250 U/h) was initiated in trauma patients who were evaluated and found to have no bleeding on computed tomography or FAST (Focused Assessment with Sonography in Trauma). For patients with fasciotomy or bleeding from the fasciotomy, heparin treatment was stopped for 2 h. If bleeding did not recur, treatment was resumed at a reduced dose of 5 IU/kg/h.

Vasodilator therapy: An IV nitroglycerin infusion was initiated at a dose of 5–10 mcg/kg/min. In severe cases, a nitroglycerin patch or nitroglycerin-soaked sponge was applied topically to the affected extremity. Milrinone (0.2–0.4 mcg/kg/min) and iloprost (0.5–1 ng/kg/min) were also used as vasodilators.

Plasma exchange method: Our protocol recommends considering TPE or referral to a specialized center within the first 24 h after achieving hemodynamic and metabolic stability in patients with severe crush injuries who are being evaluated for amputation. Continuing TPE once a day is necessary to ensure a safe healing process.

During the procedure, the patients were carefully monitored, with close attention paid to their vital signs and ionized calcium levels. Calcium gluconate support was administered when necessary to maintain calcium levels between 1–1.5 mmol/L.

In TPE procedures, the filtration method was preferred using devices such as the Prismaflex (Gambro, Lund Sweden) and MultiFiltrate (Fresenius Medical Care AG&Co KGaA, Germany). Membranes used were TPE 1000 (polypropylene, 0.15 m^2, for infants under 15 kg), TPE 2000 (polypropylene, 0.35 m^2, for children over 15 kg), and Dry Plasma Flux P1/P2 (plasmosulfone, P1 dry, for pediatric patients, 0.3 m^2; P2 dry, for adolescent patients, 0.6 m^2, Fresenius Medical Care AG&Co KGaA, Germany). To determine the volume of plasma to be replaced, the total blood volume (TBV) was calculated first using the equation TBV = 80 mL × BW(kg) for children under 3 years old and 70 mL × BW(kg) for 3 years and older. Total plasma volume was then determined using TBV × (1 - Hct/100). The TPE volume was determined by adjusting 1.5 volumes of plasma in the first session and 1 volume in subsequent sessions.

Hyperbaric oxygen therapy method (HBOT): Patients who were respiratory, hemodynamically, and metabolically stable started hyperbaric oxygen therapy (HBOT) within the first 24 h. Given the potential contraindications and complications of HBOT (such as pneumomediastinum, pneumothorax, high fever, middle ear barotrauma, claustrophobia), sessions were performed every 8 h for the first 2 days and every 12 h for the next 5 days in patients who were being evaluated for amputation. After 1 week, the frequency of HBO treatment was reduced to one session per day based on the patient's condition.

Each treatment involved applying a pressure of 2.4 ata for 90–120 min, with alternating periods of compression and decompression. Hyperbaric oxygen was administered via a mask after the patient was placed in the chamber or tank.

1.9. VAC method

Vacuum-assisted closure (VAC) therapy was utilized in patients who had undergone fasciotomy to expedite the healing of the incisions.

1.10. Tetanus prophylaxis

If the patient's tetanus vaccination history is unclear or they have received less than three doses of the vaccine, both tetanus vaccine and tetanus immunoglobulin (TIG) should be administered for contaminated wounds. Patients who have received at least three tetanus vaccines are exempt from receiving TIG if less than 5 years have passed since their last vaccination. After 5–10 years have passed, patients who have received three doses of the vaccine should only be vaccinated if the wound is dirty; otherwise, there is no need for vaccination. Patients who have received the vaccine at least three times and whose last dose was more than 10 years ago should receive another shot.

1.11. Antibiotic treatment

Sulbactam-ampicillin was administered as a prophylactic antibiotic in patients with crush injuries. For patients with dirty wounds or fasciotomy, meropenem + teicoplanin were initiated, and the antibiotics were adjusted based on culture results. If clinical findings, appearance, or odor suggested an anaerobic infection, clindamycin was added to the treatment regimen.

1.12. Stress ulcer prophylaxis

A stress ulcer prophylaxis treatment consisting of an H2 receptor antagonist or a proton pump inhibitor was administered.

1.13. Analgesics

To alleviate or prevent pain in patients, ketamine (1 mg/kg dose), fentanyl (1–2 mcg/kg/min), dexmedetomidine (0.2–0.6 mcg/kg/h), and paracetamol (4 × 10 mg/kg/dose max 500 mg) were administered. Non-steroidal anti-inflammatory drugs (NSAIDs) were not used due to their potential renal toxicity.

2. Statistic

The collected data was analyzed using the Statistical Package for Social Sciences for Windows version 23.0. Descriptive statistics, including number, percentage, mean, standard deviation, and median, were used to evaluate the data.

RESULTS

Thirteen patients (eight boys and five girls) who were referred to our hospital after the initial intervention in the earthquake area were included in this study. The patients had a mean age of 117.2 ± 46.6 months. On average, the duration of the patients under debris was 14.8 ± 13.8 h (minimum: 1 h; maximum: 42 h). Eight patients had severe crush injuries, including four extremities in one patient and both legs in another. The mean MESS score was 5.30 ± 3.27 and four of the patients had a MESS score above 7 (Table 1). Compartment syndrome developed in six of the patients (46.1%), and as a result, fasciotomy was performed in the regional intensive care unit. Debridement was required in eight patients (61.5%), and an average of 3.6 ± 3.8 debridement procedures were performed. VAC treatment was applied to seven patients (53.8%). Also, four patients had fractures, five had lung injuries, and three developed AKI.

CRRT was applied to two out of the three patients who developed AKI, while intermittent HD was applied to the remaining patient. On average, 5.2 ± 9.5 sessions of TPE treatment were administered to four patients. Eight patients received a mean of 15 ± 17.5 sessions of HBOT. None of the patients developed a systemic infection, while local wound infection developed in three patients. The mean PICU stay and hospital stay was 16.61 ± 11.15 and 32.76 ± 21.58 days respectively. All patients were discharged, and there were no fatalities. The demographic and clinical characteristics of the patients were shown in Table 1 and Figure 1.

DISCUSSION

Once patients rescued from earthquake debris had been stabilized, full intensive care services were only available at the nearest tertiary hospitals that were not affected by the earthquake. It's important to remember that healthcare professionals living in the earthquake zone were also disaster victims.

During a crisis, teamwork and understanding the dynamics of the team, as well as recognizing the limitations of team members, are crucial for effective management. It may be necessary to bring in intensive care support teams from other cities to assist in the region with their own teams.

Establishing a treatment protocol and adapting it to the treatment team is essential for standardizing interventions and quickly reaching each patient. This approach ensures that no time is wasted in providing effective care.

It is crucial to treat every patient rescued from the earthquake zone as a major trauma patient. Although trauma evaluation is typically performed in emergency departments, in the first few days after an earthquake, when the patient flow is high, it may be necessary to skip trauma evaluation and proceed directly to intensive care hospitalizations.

Upon the patient's arrival at the intensive care unit, the primary assessment is made using the ABCDE approach: A for airway patency, B for breathing, C for circulation, D for disability, including the AVPU scale (Awake, respond to Verbal stimulus, respond to Pain stimulus, Unresponsive), blood glucose levels, and light reflex, and E for exposure and head-to-toe examination, as well as a four-quadrant evaluation using FAST (4,5).

Once stabilized, the patient is referred for a computed tomography (CT) scan. Non-contrast CT scans are performed on the cranial, cervical, thoracic, abdominal, spinal, and pelvic regions, and direct radiographs of the long bones are taken. Radiology, neurosurgery, pediatric surgery, and orthopedics consultations should be obtained as needed. If emergency surgical intervention is required, it should be performed before transferring the patient to the intensive care unit, where they will receive ongoing care. Patients with severe crush syndrome require immediate treatment, starting with intravenous alkaline hydration and diuresis to correct electrolyte and acid-base imbalances. Urgent dialysis may be necessary, and maintaining hemodynamic and metabolic balance is critical (6,7).

In crush syndrome, damaged muscles can release myoglobin and intracellular enzymes, such as lactate dehydrogenase, creatine kinase, and uric acid, into the bloodstream, leading to myoglobinuria and potentially causing obstruction and acute tubular necrosis (8). Adequate hydration and diuresis are critical to prevent this accumulation. The furosemide stress test is a useful objective test of tubular function that can be used in patients with crush syndrome (9). If the test is unsuccessful, fluid restriction and dialysis preparation should begin. The patient's hemodynamics, device and circuit availability, and the experience of the nursing staff determine the preferred dialysis method (10). In patients with stable vital signs, intermittent hemodialysis is preferred. Rather than transferring patients to the hemodialysis unit, it may be more practical to dedicate an intensive care room to hemodialysis and include hemodialysis nurses as part of the intensive care team to provide uninterrupted service (11). CRRT should be used for unstable patients requiring dialysis. High-volume continuous venovenous hemodiafiltration (CVVHDF) may be the preferred therapeutic approach for patients undergoing CRRT. This approach may effectively eliminate macromolecules such as myoglobin and large volumes of cytokines generated after trauma (12,13).

Hyperkalemia is another life-threatening condition frequently encountered in patients rescued from earthquake zones, and it is the one of most common causes of death after trauma. As stated in the protocol, if medical treatment of hyperkalemia is unsuccessful, dialysis should not be delayed (14).

The Role of Pediatric Intensive Care in Compartment Syndrome and Amputation Decision

Compartment syndrome is one of the most important problems that can develop in patients due to the crushing

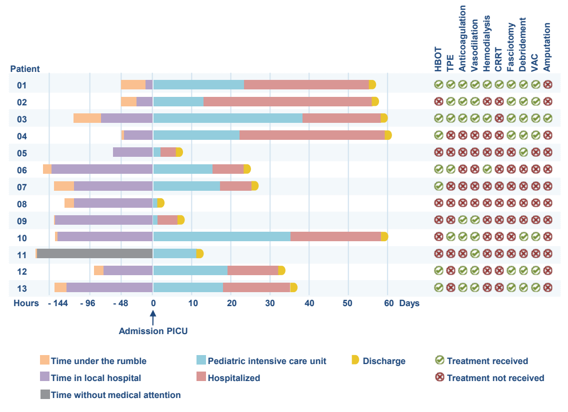
Table 1: Characteristic features and laboratory results of the earthquake victims

	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10	Pt 11	Pt 12	Pt 13
Age (month)	198	124	73	165	157	59	52	99	181	118	80	116	102
Sex	Girl	Boy	Boy	Girl	Boy	Girl	Boy	Boy	Boy	Girl	Boy	Boy	Girl
Weight (kg)	59	60	21	40	48	18	14.6	37	43	47	20.1	58	37.5
BMI (kg/m2)	20.4	21.3	12.4	19.8	21.3	10.65	12.07	21.89	15.76	20.89	21	22.97	20.03
Rescue time (hour)	38	24	42	4	1	14	24	12	1	4	2	12	15
Extremities subjected to crushing	Left leg	Left leg	Left leg	Right leg	Right leg	Right ab. flank	Right & left leg	Right foot	Left leg	Four extremities	Left foot	Right leg	Right leg
MESS score	10	10	10	3	2	5	3	2	2	8	2	6	6
Fracture	+	-	-	+	-	-	-	-	-	+	-	-	+
Lung injury	+	-	-	-	-	+	-	-	+	+	-	+	-
Acute kidney injury	+	-	-	-	-	+	-	-	-	-	-	-	-
Local infection	-	+	+	-	-	-	-	-	-	+	-	-	-
Systemic infection	-	-	-	-	-	-	-	-	-	-	-	-	-
DIC	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of surgical operations performed	5	4	7	10	1	0	0	0	0	10	0	6	4
Number of TPE	22	14	27	0	0	4	0	0	0	2	0	0	0
Number of sessions HBOT	40	50	30	2	0	18	20	0	0	0	0	6	29
Laboratory Results on Admission													
Hemogram													
HGB (g/dL)	17.4	9.6	15.6	9.1	12.5	8.6	8.6	13.0	8.4	7.9	14.7	10.4	8.7
PLT (103/uL)	384	260	508	154	350	388	348	361	256	271	283	460	409
WBC (103/uL)	21.29	12.57	23.4	9.49	6.82	10.34	11.2	11.29	8.96	12.7	13.07	25.19	9.55
NEU (103/uL)	17.75	8.60	6.8	6.1	4	7.3	8.6	7.6	5.2	9.5	7.4	17.3	8.5
LYM (103/uL)	1.46	2.9	2	0.7	1.9	0.6	1.7	2.4	2.3	2.2	4.5	5.8	0.9
Biochemistry													
BUN (mg/dL)	22	11	27	11	10	7	6	10	8	6	14	12	5
Urea (mg/dL)	47	224	58	24	21	15	12	21	17	12	31	25	11
Creatinine (mg/dL)	1	0.4	0.4	0.5	0.5	0.3	0.3	0.4	0.5	0.4	0.5	0.5	0.3
Uric Acid (mg/dL)	6.8	5.6	9.1	4.1	3.3	0.9	1.8	2.6	3.4	2.8	5.2	5.4	2.3
Sodium (mmol/L)	133	132	136	139	142	138	137	137	141	140	123	134	139
Potassium (mmol/L)	5.4	4.3	5	3.9	4.2	4.5	4.1	4	4.2	3.5	5	3.5	3.9
Calcium, total (mg/dL)	8.4	9.1	10.2	7.2	10.2	9.7	8.4	9.9	9.4	8.8	8.5	8.9	9.3
Phosphorus (mg/dL)	7.2	2.9	5	3.5	4.2	4.2	3.7	5.2	4.6	3.4	5.3	3.9	4.8
Serum albumin (g/L)	26.8	23.9	45	23.3	47.7	38.1	27.4	40.3	41.4	34.3	24.6	32.2	36.7
AST (u/L)	1910	565	285	100	18	250	1621	73	24	101	22	206	78
ALT (u/L)	695	264	131	29	18	112	405	29	14	93	11	152	67
LDH (u/L)	4500	564	1500	214	205	965	2429	283	281	546	246	659	444
Amylase (u/L)	19	12	24	14	20	30	13	14	15	12	10	18	20
Creatine Kinase (u/L)	134117	6030	120000	3547	2200	9587	52000	1184	1130	2914	620	10085	3264
Urine analysis													
pH	6	7	9	9	6	9	9	8	8	9	7	7	8
Protein (mg/dL)	100	30	0	0	0	15	15	0	15	30	0	0	0
Hemoglobin	3	0	0	0	0	0	2	0	3	1	0	0	0
Density	1037	1037	1010	1010	1008	1013	1007	1012	1015	1016	1003	1009	1004
Myoglobin (µg/L)	5800	65	32	83	8	8	5940	8	8	8	0	8	8

Table 1: Continue

	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10	Pt 11	Pt 12	Pt 13
Laboratory Results of the Last Work Up													
Hemogram													
HGB (g/dL)	9.6	11	7.9	10.7	13.0	12.3	10.4	12.8	8.6	7.2	13.2	11.4	9.7
PLT (103/uL)	467	388	497	218	244	282	423	284	389	446	434	122	507
WBC (103/uL)	9.28	9.55	4.68	8.13	4.97	5.54	5.6	9.89	9.95	11.12	11.72	6.76	5.05
NEU (103/uL)	5.5	4.8	2	5.2	3.1	1.8	2.4	7.4	7.5	6.9	7.1	3.4	2.2
LYM (103/uL)	2.3	4.1	2.2	1.9	1.3	3.2	2.1	1.4	1.5	3	3.2	2.6	1.8
Biochemistry													
BUN (mg/dL)	8	8	14	6	11	9	3	10	10	8	7	11	10
Urea (mg/dL)	18	17	29	13	23	20	7	21	21	17	16	24	22
Creatinine (mg/dL)	0.6	0.4	0.2	0.5	0.5	0.2	0.2	0.4	0.4	0.4	0.3	0.4	0.4
Uric Acid (mg/dL)	3.1	4.7	2.5	3	5.3	3.2	2.9	3.4	2.4	2.6	4.7	6.8	3.4
Sodium (mmol/L)	141	135	141	142	140	140	141	141	138	138	127	142	140
Potassium (mmol/L)	3.7	4	4.2	3.9	4.6	4.8	3.1	4.2	4.7	4.4	3.6	4.1	4.7
Calcium (mg/dL), total	8.9	10.4	10.2	9.6	9.7	11.3	10.1	9.8	9.6	9.4	9.1	10.5	10.4
Phosphorus (mg/dL)	3.9	5.2	4.9	4.4	3.9	5.3	5.4	5	4.7	5.8	4.2	5.6	5.8
Serum albumin (g/L)	40.1	43.1	47.2	33.4	46.9	47.4	40.5	45.9	39.6	27.5	30.2	47.9	43.6
AST (u/L)	21	31	26	20	32	32	46	24	21	23	23	54	26
ALT (u/L)	21	27	22	24	63	23	25	21	16	19	9	77	32
LDH (u/L)	209	250	105	183	171	411	437	188	209	354	135	242	213
Amylase (u/L)	15	12	10	13	15	8	10	12	13	10	9	8	12
Creatine Kinase (u/L)	71	105	45	13	40	214	132	121	50	30	71	87	50
Urine analysis													
pH	7	7	8	7	5	7	7	7	8	9	7	6	8
Protein (mg/dL)	0	0	0	15	0	0	0	0	0	0	0	0	0
Hemoglobin	0	0	0	0	0	0	0	0	0	0	0	0	0
Density	1009	1014	1005	1012	1016	1012	1005	1030	1015	1015	1006	1015	1013
Myoglobin µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0

ab.: abdominal, ALT: alanine transaminase , AST: aspartate aminotransferase, BMI: body mass index, BUN: blood urine nitrogen, DIC: disseminated intravascular coagulation, HBOT: hyperbaric oxygen therapy, HGB: hemoglobin, LYM: lymphocyte, LDH: lactate dehydrogenase, MESS: mangled extremity severity score, NEU: neutrophil, PLT: platelet, TPE: therapeutic plasma exchange, WBC: white blood cells



HBOT, hyperbaric oxygen therapy; TPE, therapeutic plasma exchange; VAC, vacuum-assisted closure; CRRT, continuous renal replacement therapy

Figure 1: Timeline of the post-earthquake process and the treatments received by the patients

of the extremities (15). To manage this condition, the affected extremities should be elevated above heart level, and pain control measures (such as ketamine, fentanyl, dexmedetomidine, and paracetamol) should be provided. Additionally, patients should be closely monitored for signs of compartment syndrome, with urine output monitored and hypervolemia avoided. A slit catheter that inserted to compartment and connected to an arterial line transducer that can be used to measuring of compartment pressure. An intra-compartmental pressure over 30 mmHg is defined as compartment syndrome. Delta pressure is another way to evaluate compartment pressure that is equal to diastolic pressure minus measured intracompartment pressure. Delta pressure less than or equal to 30 mmHg is an indication of the need for fasciotomy (16). We did not measure the compartment pressure however crushed extremities were carefully evaluated through physical examination to determine the need for fasciotomy and doppler US was used to evaluate blood flow, occlusion, and thrombus formation. Prophylactic fasciotomy in the absence of measured compartment pressure elevation should be avoided (17, 18).

In clinically and hemodynamically stable patients, even if there are signs that may require extremity amputation (such as coldness, ecchymosis, ischemia, absence of pulse, and absence of blood flow on Doppler US), a decision for amputation should not be made hastily. However, following up with these patients without amputation in hospitals in the earthquake zone, where patient flow is high, can be risky and may lead to overlooking systemic complications and potentially losing patients. Such patients should be referred to tertiary centers with comprehensive facilities, including hyperbaric oxygen therapy, therapeutic plasma exchange, orthopedics, and plastic surgery, where they can be more closely monitored, and the decision for amputation should be left to the referred center. Suppose the clinical condition requires urgent amputation (such as severe systemic inflammatory response syndrome, bleeding, sepsis, or gas gangrene). In that case, a decision should be made based on the patient's needs to prevent systemic and life-threatening complications (19).

Intensive Care Management of a Patient Considering Amputation

In the Kahramanmaraş earthquake of 2023, we observed that four patients with crush injuries and who were considered for amputation (their MESS score =10) and were clinically stable had their extremities revascularized using a protocol that we initiated in the primary earthquake zone and continued in our center (Figure 2).

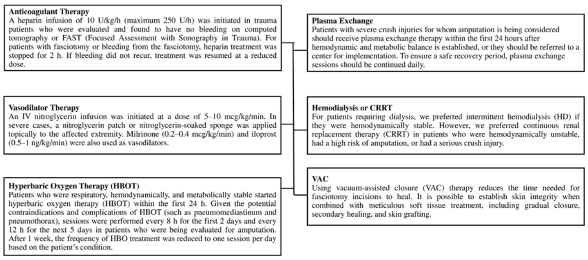


Figure 2: Treatment protocol for pediatric intensive care management of the patients considering amputation

The protocol aims to maintain microcirculation and prevent distal ischemia and necrosis. For patients with severe crush injuries and reduced or no blood flow on Doppler US, heparin infusion was initiated (provided there was no bleeding on FAST and CT imaging) to prevent microthrombus formation in the extremities. We used the doses specified in the protocol and observed no treatment-related bleeding or new thrombus formation in any patient. The main advantage of heparin over low molecular weight heparin is its shorter half-life of 2 h and the availability of an antidote (protamine sulfate) in case of possible bleeding when treatment is discontinued (20,21). Likewise, vasodilator therapies such as intravenous or topical nitroglycerin, milrinone, and iloprost (in patients with reduced or absent arterial phase flows) were employed to maintain microcirculation and enhance perfusion in the extremities. Ilioprost, a synthetic analog of prostaglandin I_2, acting as a potent inhibitor of platelet aggregation and a vasodilator is used in maintaining microvascular circulation of dermal flap in reconstructive surgery and enhance perfusion of ischemic limb in frostbite (22,23).Similarly, nitroglycerin was used in dermal necrosis of soft tissue augmentation surgery and treating vasopressor related digital ischemia in septic shock in previous studies showed to improve flow in dermal vasculature and digital extremities respectively (24,25). When used at the specified doses in our protocol, no treatment-related complications or hypotension were observed in any patient (26).

Ischemic extremities without blood flow can lead to serious systemic and life-threatening events such as thrombocytopenia-related multiple organ failure (TAMOF), systemic inflammatory response syndrome (SIRS), disseminated intravascular coagulation (DIC), sepsis, and gas gangrene. Even transferring a patient with this condition to a tertiary center can pose a significant risk due to potential systemic complications that may develop en route. TPE therapy has proven to provide a safe recovery period, allowing for the safe transfer of patients to tertiary centers and more frequent and longer HBOT for complete recovery or limb-sparing surgery with the establishment of the demarcation line. In previous years, TPE has been used to treat sepsis, TAMOF, and DIC (27). The experience with TPE in crush injury has not yet been reported, however, Klein et al showed the beneficial effect of TPE in severe burn injuries previously (28). Considering the same pathophysiology of the event, crush injury can cause severe endothelial damage, leading to a cytokine storm and SIRS, as well as excessive endothelial exocytosis and the release of large amounts of ultra-large von Willebrand Factor (uLvWF) into circulation, which can lead to microthrombi formation and platelet aggregates. ADAMST-13, an enzyme needed to degrade uLvWF, may be insufficient, leading to the deposition of uLvWF on the endothelium and the formation of microthrombi, impairing organ perfusion and leading to multiple organ failure (29). TPE therapy provides clearance of both pro-inflammatory mediators of the inflammatory pathway and elements of the microthrombotic pathway. The timing of TPE therapy initiation is critical to achieving the benefits of this treatment (30). One of four patients, who had a more severe crush injury and was under the rubble for a similar duration, recovered without the need for amputation due to the early initiation of TPE (on the second day of the earthquake), HBOT and the application of the protocol (Patient 1 in Figure 1). In contrast, the other patient, who had a less severe crush injury and received treatment late (on the sixth day of the earthquake), had to undergo partial amputation distal to the metatarsal joint, although below-knee amputation was ultimately avoided (Patient 3 in Figure 1). This patient was initially followed up in the ward due to their stable clinical condition but was later admitted to the intensive care unit on the sixth day with a plan for above-knee amputation due to impaired leg circulation. This patient highlights the importance of early recognition of extremity changes for pediatricians following up with patients in the ward.

Intensive Hyperbaric Oxygen Therapy (HBOT)

HBOT increases not only the dissolved partial oxygen pressure in the blood but also mitochondrial oxygenation (31). As oxygen cannot be delivered to the necrotic extremities with impaired vascularity through blood, the increase in partial oxygen pressure and the provision of oxygenation at the mitochondrial level can halt the progression of necrosis in the extremities.

HBOT helps maintain aerobic respiration in all cells and tissues, ensuring survival. Moreover, it has an anti-edema effect by increasing extravascular fluid resorption. By maintaining aerobic metabolism, it can prevent the growth of anaerobic organisms and create a sterile environment (32). One of the most important effects of HBOT is its ability to stimulate collagen synthesis and fibroblast migration, thereby accelerating wound healing. Moreover, it has an anti-edema effect by increasing extravascular fluid resorption. Jirangkul et al suggested that HBOT should be considered in limb salvage procedures to manage extremities of which MESS was over 7. They included 18 patients with severe mangled limbs (MESS ≥ 7). Adjunctive to surgical procedure, the patients received HBOT within 48 hours of injury twice daily for the first three days then following once daily (number of HBOT mean 23.44 ± 6.76). Only one patient (MESS = 12) needed below knee amputation (32). Therefore, in our protocol, patients who were initially considered for amputation (MESS > 7) received intensive HBOT treatment, with hyperbaric therapy administered every 8 h for the first 2 days, every 12 h for the next five days, and finally, daily hyperbaric therapy, resulting in remarkable outcomes.

Vacuum-Assisted Closure (VAC)

Prior research has indicated that VAC treatment can decrease the time needed for fasciotomy incision healing (33). Using the VAC method in treatment has significantly reduced edema in the extremity, which can delay wound healing. Additionally, orthopedic, and plastic surgery procedures performed by a skilled surgical team in the patients' follow-up have made an invaluable contribution to creating a functional limb.

Record-board (Writing whiteboard)

The use of a whiteboard (Figure 3) is crucial for facilitating the follow-up of intensive treatments given to patients by both nurses and doctors, as well as adjusting the timing and coordination of treatment in regional PICUs where there is a high patient flow and in tertiary PICUs where patients are

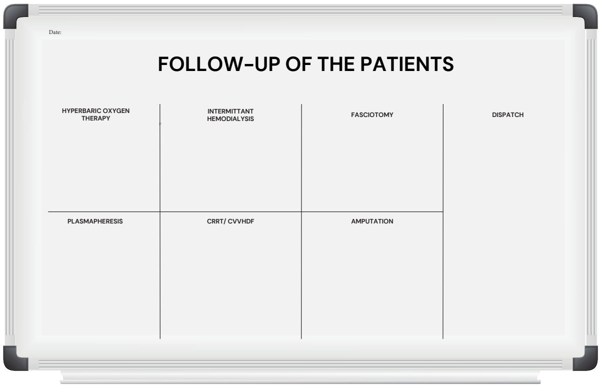


Figure 3: Recording board for adjusting the timing and coordination of treatment in regional PICUs where there is a high patient flow and in tertiary PICUs where patients are referred.

referred. According to Justice et al., using record boards that visually present patients' daily goals enhances communication during multidisciplinary rounds in cardiac critical care units where intensive patient follow-up is conducted (34).

Dispatch

Maintaining the referral network in motion is also crucial (35). Patients at risk of amputation should be referred to tertiary centers in a coordinated manner after metabolic and hemodynamic stabilization has been achieved in primary centers with high patient flow following an earthquake. To avoid communication issues between the center where the patient is being transferred, the emergency coordination center, and the center where the patient will be referred, it was helpful to create a transfer form similar to the one shown in Figure 4.

	Patient Name	Security Number	Age	Diagnosis/Crushed Extremities	Respiration	Vitals	Received treatments	Referral Center	Doctor contact in referral center
First Dispatch									
Second Dispatch									

Figure 4: Transfer form for maintaining the referral network

It is crucial to record the earthquake victim's identity information on the transfer form to ensure that it can be applied again during transport or later if their identity is determined.

CONCLUSION

Disasters cannot be controlled, and this reality highlights the need for rigorous, controlled, and systematic protocols to be prepared in advance and implemented in the event of a disaster that will impact society in many ways. Developing a treatment plan that includes standardized interventions for healthcare teams in major disasters is crucial. In this study, we present the treatment plan that we experienced during the 2023 Kahramanmaraş earthquake to be prepared and ready for future disasters.

Patients at risk of amputation should be referred to tertiary centers in a coordinated manner after metabolic and hemodynamic stabilization has been achieved in primary centers with high patient flow following an earthquake. Specialized treatments such as daily TPE therapy with frequent HBOT, anticoagulant and vasodilator treatments, and VAC therapy initiated in regional PICUs and continued in tertiary referral PICUs can produce encouraging results for patients with severe crush syndrome.

Ethics Committee Approval: This study was approved by the ethics committee Koç University (approval number: 2023.133.IRB1.045).

Informed Consent: Written consent was obtained from the participants.

Peer Review: Externally peer-reviewed.

Author Contributions: Conception/Design of Study- M.T., I.B., .Ö.Ö.; Data Acquisition- A..Ç, L.Ö., K.S., M.E.M.; Data Analysis/Interpretation- İ.E., A.Ç.; Drafting Manuscript- M..T, İ.B., K.S., Ö.Ö.; Critical Revision of Manuscript- İ.E., A.Ç., A.Ç., L.Ö., M.E.M.; Final Approval and Accountability- M.T., I.B., Ö.Ö., K.S., A.Ç., L.Ö., İ.E, A.Ç., M.E.M.

Conflict of Interest: Authors declared no conflict of interest.

Financial Disclosure: Authors declared no financial support.

Etik Komite Onayı: Bu çalışma Koç Üniversitesi etik kurulu tarafından onaylandı (onay numarası: 2023.133.IRB1.045).

Bilgilendirilmiş Onam: Katılımcılardan bilgilendirilmiş onam alınmıştır.

Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Çalışma Konsepti/Tasarım- M.T., I.B., .Ö.Ö.; Veri Toplama- A..Ç, L.Ö., K.S., M.E.M.; Veri Analizi/Yorumlama- İ.E., A.Ç.; Yazı Taslağı- M..T, İ.B., K.S., Ö.Ö.; İçeriğin Eleştirel İncelemesi- İ.E., A.Ç., A.Ç., L.Ö., M.E.M.; Son Onay ve Sorumluluk- M.T., I.B., Ö.Ö., K.S., A.Ç., L.Ö., İ.E, A.Ç., M.E.M.

Çıkar Çatışması: Yazarlar çıkar çatışması beyan etmemişlerdir.

Finansal Destek: Yazarlar finansal destek beyan etmemişlerdir.

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