Journal of Pediatric Emergency and Intensive Care Medicine

Çocuk Acil ve Yoğun Bakım Dergisi

TURKISH SOCIETY OF PEDIATRIC EMERGENCY AND INTENSIVE CARE MEDICINE

Volume / Cilt: 13 **Issue / Sayı:** 2 **Year / Yıl:** 2026

E-ISSN: 2148-7332

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Phone: +90 322 338 60 60 / 3654
E-mail: dergi@caybdergi.com

The Journal of Pediatric Emergency and Intensive Care Medicine is a publication of "Society of Pediatric Emergency and Intensive Care Medicine".
Çocuk Acil ve Yoğun Bakım Dergisi, Çocuk Acil Tıp ve Yoğun Bakım Derneği'nin bilimsel yayınıdır.

Publisher Contact/Yayınevi İletişim
Address/Adres: Molla Gürani Mah. Kaçamak Sk. No: 21/1 34093 İstanbul, Türkiye
Phone/Telefon: +90 (530) 177 30 97
E-mail/E-posta: info@galenos.com.tr/yayin@galenos.com.tr
Web: www.galenos.com.tr
Publisher Certificate Number/Yayıncı Sertifika No: 14521

Publication Date/Yayın Tarihi: August 2026/Ağustos 2026
ISSN: 2146-2399 **E-ISSN:** 2148-7332

International periodical journal published three times in a year.
Yılda üç kez yayımlanan süreli yayındır.

Journal of Pediatric Emergency and Intensive Care Medicine

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Owner: Turkish Society of Pediatric Emergency and Intensive Care Medicine

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From the Editor

When Practice Outruns Evidence: Custom, Structure, and Access in Pediatric Critical Care

Pediatric emergency medicine and pediatric critical care are not simply the settings in which severe illness is managed. They are the disciplines in which evidence must be converted into bedside judgment under maximal time pressure. Three developments of the past several months shaped the preparation of this issue.

The first was the March 2026 publication of the Surviving Sepsis Campaign international guidelines for sepsis and septic shock in children.[1] A panel of 68 international experts representing 13 organizations, supported by 6 methodologists, updated the 2020 guideline and issued 61 statements, 20 of them new. The principal conceptual shift is the move away from definitions based on the systemic inflammatory response syndrome toward organ-dysfunction criteria. Under the 2024 Phoenix consensus criteria, a score of 2 or higher was associated with in-hospital mortality of 7.1% in higher-resource settings and 28.5% in lower-resource settings.[1,2] Several recommendations reach the bedside directly: conditional support for cardiac and lung point-of-care ultrasound to guide resuscitation, a conservative oxygenation target for intubated children after resuscitation, and a conditional recommendation favoring high-volume hemofiltration when renal replacement therapy is required. The panel also found insufficient evidence to recommend co-treatment with methylene blue for children with persistent hypoperfusion despite other vasoactive medications, a conclusion directly relevant to one of the series published here.[1]

The second was GASTRIC-PICU, published online in JAMA on June 12, 2026.[3] In a pragmatic non-inferiority trial across 23 pediatric intensive care units (PICUs) in the United Kingdom and 1 in Switzerland, 4700 invasively ventilated, gastrically fed children were randomized to no routine gastric residual volume assessment or to assessment at least every 6 hours. Omission met the noninferiority margin for the clinical composite of survival and ventilator-free days at day 30 [adjusted odds ratio, 0.95; 95% confidence interval (CI), 0.86-1.05] and modestly improved energy delivery at 72 hours (80.3% vs. 76.8%; adjusted mean difference, 3.24 percentage points; 95% CI, 1.29-5.19), with no excess of ventilator-associated pneumonia or necrotizing enterocolitis.[3] The trial is best read as a deimplementation study. A practice sustained for decades on physiological plausibility alone was finally tested at scale, and the assumption underlying it did not survive the test. The lesson concerns method rather than feeding.

The third development moves beyond physiology to the architecture of care. By the end of 2025, 117.8 million people were forcibly displaced worldwide, an estimated 45 million of them children.[4] For pediatric emergency departments, that figure is not sociological background. It is a condition of practice. A recent multicenter study from İstanbul offers a national parallel: among 5685 PICU admissions during 2023 across 10 units, 53 children had laboratory-confirmed measles, with a median age of 1.3 years, and 81.1% were classified as unvaccinated for the analysis.[5] The absolute numbers are small, but the preventive signal is not, and it ties preventive pediatrics to critical care more tightly than we have been accustomed to assume.

The clinical contributions in this issue fall into three groups.

The first concerns refractory shock, extracorporeal support, and renal replacement. Ekren and colleagues report 125 continuous renal replacement therapy (CRRT) procedures in 85 children, with shorter filter survival on heparin than on citrate (p=0.002) and an association between pretreatment acidemia, low bicarbonate, elevated lactate, and mortality.[6] The anticoagulation finding is consistent with a 2025 meta-analysis of 638 pediatric patients,[7] although a retrospective single-center design cannot exclude confounding by indication, since heparin is preferentially withheld from children already at risk of bleeding. Read with that caution, the study contributes national data to a question the international literature has not settled. Emer Dilaver et al.[8] describe methylene blue in 10 children with catecholamine-resistant shock: systolic pressure rose significantly, the vasoactive-inotropic score did not respond consistently, and 90% died. The authors interpret this as a consequence of late administration in an extremely ill cohort rather than lack of drug effect, an interpretation that is plausible but that a series of this size and

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design cannot distinguish from the alternative. Given that the Surviving Sepsis Campaign panel found the evidence base too thin to support any recommendation,[1] transparently reported series of this kind, including those with disappointing results, are necessary for defining the hypotheses that future comparative studies will need to test. The letter from Özcan et al.[9] extends the discussion from physiology to system design: half of Turkish centers transfer their candidates for extracorporeal membrane oxygenation (ECMO), annual case volume falls below 5 in 80% of centers offering the technique, and the unavailability of double-lumen cannulae for infants pushes units toward venoarterial support. The constraint here is access, not technology.

Trauma, toxicology, and neurologic emergencies form the second group. İrday et al.[10] document thoracic injury in 29% of 375 trauma admissions over 7 years, with tube thoracostomy in 53.2%, surgery in 11.9%, and significantly prolonged intensive care stay ($p=0.002$). The fact that earthquake-related injuries ranked second among injury mechanisms is a reminder that disaster preparedness is not theoretical in this region. In a cohort of 391 acute poisonings, İldeş et al.[11] sharpen the age-dependent distinction between accidental domestic exposure in young children and intentional ingestion in adolescents ($p<0.001$). The concentration of rodenticide exposure among the youngest is a public health and regulatory concern, not only a clinical one. The protocol by Kocaoğlu et al.[12] on raised intracranial pressure, covering optic nerve sheath diameter measurement, thresholds for hyperosmolar therapy, and the move away from routine hyperventilation, is one of the most immediately useful contributions in this issue for trainees.

The third group comprises case reports, each of which tests a boundary of clinical reasoning. Battal et al.[13] describe commotio cordis following peer bullying, with subsequent hypoxic-ischemic encephalopathy. The case shows that commotio cordis should not be regarded as a phenomenon confined to organized sport, and that outcome depends on how rapidly defibrillation is delivered, a point reinforced by the 2025 resuscitation guidelines' emphasis on rapid recognition and defibrillation.[14] Balkan et al.[15] report bilateral pulmonary embolism in a child with Klippel-Trenaunay syndrome, instructive for its early echocardiographic risk stratification and for conservative anticoagulation in a hemodynamically stable intermediate-risk presentation; their restraint in not inferring causality from the association with sirolimus is methodologically appropriate.[15] Qureshi and Futela,[16] reporting a late neonatal humeral shaft fracture with bridging callus, return us to the discipline of differential diagnosis: birth trauma, inflicted injury, and bone fragility cannot be separated on a single radiograph.

Not every advance in critical care arrives as a measurement. Demir Acar et al.[17] interviewed 12 pediatric emergency nurses about caring for refugee children and their families and documented increased workload, language barriers that interrupt both treatment and discharge teaching, the emotional weight of encountering neglect, and a determination to treat every child alike despite those pressures. Twelve participants cannot establish prevalence, and the study does not claim to. What qualitative work of this kind can show, and quantitative work may not capture as readily, is the mechanism by which social conditions become clinical risk. A discharge instruction that is not understood is functionally equivalent to one that was never given.[4,17] Secondary traumatic stress among staff belongs among our quality indicators and is not yet there.

Taken together, these papers describe a field that can no longer be satisfied with asking what should be done. The more exacting question is this: on what evidence, within which system constraints, and with recognition of which inequities do we act? GASTRIC-PICU shows what happens when that question is finally put to a practice that had never faced it. The same scrutiny has not yet been applied to much of what we do in refractory shock, pediatric CRRT anticoagulation, and ECMO triage. This issue measures that distance.

I thank the authors and reviewers whose work made this issue possible.

Prof. Hayri Levent Yılmaz, MD.

Editor-in-Chief

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DOI: 10.4274/cayd.galenos.2026.35467
J Pediatr Emerg Intensive Care Med 2026;13(2):79-85

Evaluation of Thoracic Traumas Observed in Pediatric Intensive Care Unit

Çocuk Yoğun Bakım Ünitesinde İzlenen Torasik Travmaların Değerlendirilmesi

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Abstract

Introduction: To discuss findings and interventions of patients followed in the pediatric intensive care unit due to trauma accompanied by thoracic injury over a seven-year period, including the February 2023 Türkiye earthquake, with case examples.

Methods: Electronic health records of patients admitted to the pediatric intensive care unit due to trauma between March 2018 and 2025 were reviewed.

Results: Among the 375 trauma patients, 29% had accompanying thoracic trauma. The most common causes of trauma were traffic accident, earthquake-related injuries and falls from height. Tube thoracostomy was performed in 53.2% of patients, surgical treatment in 11.9%, bronchoscopy in 8.26%, and mechanical ventilation in 33.9%. The most common findings observed in these patients were pulmonary contusion and pneumothorax. The most frequent accompanying injuries in patients with thoracic trauma were head trauma, femur fracture, and liver and/or spleen laceration. Clinical findings, radiological images and interventions on five representative cases of patients followed in the pediatric intensive care unit due to trauma with accompanying thoracic injury is presented in this study.

Conclusion: During the primary assessment of patients, life-threatening conditions defined as the lethal six must be urgently investigated. In the presence of traumatic pneumothorax, hemothorax, or hemopneumothorax, early tube thoracostomy should be performed if the patient is symptomatic. Pulmonary contusion should be considered in blunt trauma, and pulmonary laceration in penetrating trauma. Persistent pneumothorax and hemothorax despite tube thoracostomy require surgical intervention. When pneumomediastinum and subcutaneous emphysema are detected, tracheobronchial injury should be suspected, and the patient should be evaluated for bronchoscopy.

Keywords: Critical pediatric patients, multiple trauma, thoracic trauma, surgical intervention, lethal six

Öz

Giriş: Şubat 2023 Türkiye depremini de içeren yedi yıllık sürede travma nedeni ile çocuk yoğun bakım ünitesinde izlenen ve toraks travması eşlik eden hastaların bulgularını ve uygulanan girişimleri olgular eşliğinde tartışmak amaçlanmıştır.

Yöntemler: Travma nedeni ile Mart 2018-2025 yılları arasında çocuk yoğun bakım ünitesine kabul edilen hastaların elektronik sağlık kayıtları incelendi.

Bulgular: Üç yüz yetmiş beş travma hastasına %29 toraks travması eşlik etmekteydi. Travmanın en sık nedeni trafik kazası, deprem ilişkili yaralanma ve yüksekten düşmedir. Toraks yaralanması olan hastalarda tüp torakostomi %53,2, cerrahi tedavi %11,9, bronkoskopi %8,26 ve mekanik ventilasyon %33,9 gerekli olmuştu. En sık komplikasyon pulmoner kontüzyon ve pnömotorakstı. Hastalarda toraks yaralanmasına en sık kafa travması, femur fraktürü, karaciğer ve/veya dalak laserasyonu eşlik etmekteydi. Toraks travması nedeniyle çocuk yoğun bakımda izlenen beş hastaya ait klinik bulgular, radyolojik görüntüler ve uygulanan tedaviler sunuldu.

Sonuç: Hastaların ilk değerlendirmesi sırasında ölümcül altılı olarak tanımlanan hayatı tehdit eden durumların acilen araştırılması gereklidir. Travmatik pnömotoraks, hemotoraks veya hemopnömotoraks varlığında hasta semptomatik ise erken tüp torakostomi uygulanmalıdır. Künt travmalarda pulmoner kontüzyon, penetran travmalarda pulmoner laserasyon akla gelmelidir. Tüp torakostomiye rağmen persiste eden pnömotoraks ve hemotoraks cerrahi müdahale gerektirir. Pnömomediastinum ve cilt altı amfizem saptandığında trakekobronşial yaralanma akla gelmeli, bronkoskopi açısından hasta değerlendirilmelidir.

Anahtar Kelimeler: Kritik çocuk hasta, çoklu travma, toraks travması, cerrahi tedavi, ölümcül altılı

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Received/Geliş Tarihi: 18.11.2025 **Accepted/Kabul Tarihi:** 05.02.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: İrday K, Erhan MD, Arslan İ, Özçelik Z, Parlakgümüş C. Evaluation of thoracic traumas observed in pediatric intensive care unit. J Pediatr Emerg Intensive Care Med. 2026;13(2):79-85

Introduction

Traumas are sudden injuries that pose a threat to life. Across all age groups, they are the third leading cause of death after cardiovascular diseases and cancer. Thoracic trauma occurs in 4-10% of children and has a mortality rate of approximately 5%. However, thoracic injuries are more frequently associated with multiple traumas, in which case the mortality rate may rise as high as 40%. Blunt trauma resulting from traffic accidents and falls from height accounts for 60-85% of thoracic injuries. Penetrating trauma caused by sharp objects (e.g., knives) or firearms less frequently causes thoracic injury.[1-3]

Major thoracic injuries are referred to as the "deadly dozen". During the primary assessment of patients, six life-threatening conditions, collectively known as the lethal six (airway obstruction, tension pneumothorax (PTX), PTX, massive hemothorax (HTX), flail chest, and pericardial tamponade), must be investigated urgently. During the secondary assessment, potential life-threatening conditions known as the hidden six (thoracic aortic injury, tracheobronchial injury, blunt myocardial injury, diaphragmatic injury, esophageal injury, and pulmonary contusion) should be examined.[4,5] Patients are generally treated with airway management, supplemental oxygen, tube thoracostomy, and analgesia, while approximately 10% require surgical intervention. In children, because of the greater elasticity of the thorax and bones, pulmonary injury may occur even in the absence of chest wall damage. Clinical findings may range from mild respiratory distress to respiratory arrest. Therefore, the diagnosis of life-threatening conditions depends on a high index of suspicion early surgical consultation, and timely intervention.[6-8]

Over the past 20 years, the world has had to cope with numerous disasters such as pandemics, earthquakes, tsunamis, and floods. Children, owing to their unique anatomical and developmental characteristics, constitute the population most affected by trauma. The most recent example of this is the February 2023 Türkiye earthquake, which resulted in the deaths and injuries of thousands of people in our country. Healthcare professionals were required to intervene simultaneously in hundreds of trauma cases. Physicians dealing with critically ill patients must be well-equipped to recognize conditions such as thoracic injuries that require urgent evaluation and intervention.[9-11] This study aimed to discuss the findings and interventions for patients admitted to the pediatric intensive care unit (PICU) for trauma accompanied by thoracic injury over a seven-year period, including cases from the February 2023 Türkiye earthquake, illustrated with case examples.

Materials and Methods

This cross-sectional study was conducted in the PICU of University of Health Sciences Türkiye, Adana City Training and Research Hospital, a tertiary referral center with 30 beds.

Inclusion Criteria

The study period covered admissions between March 2018 and March 2025. The study included children aged 1-216 months who were admitted to the PICU for trauma. Patient data were obtained retrospectively from the electronic health record system. Age, sex, admission date, medical history, cause of trauma, trauma region, medical or surgical interventions, pediatric trauma scores (PTS), radiological imaging findings, medical and surgical treatments, length of stay in the PICU, and clinical outcome were recorded.

Exclusion Criteria

Patients who were followed in the PICU for non-traumatic causes. Patients who were monitored in other intensive care units such as anesthesia or neurosurgery ICUs. Patients whose follow-up and treatment were completed in the pediatric emergency department were subsequently discharged.

Ethical approval was obtained from the Ethics Committee for Scientific Research of University of Health Sciences Türkiye, Adana City Training and Research Hospital (approval no: 733, date: 25.09.2025). Due to the retrospective design of the study, informed consent was not obtained from the patients' relatives.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as median (25^{th}-75^{th} percentile, interquartile range) or mean ± standard deviation, depending on their distribution. Normality was assessed separately for each group using the Shapiro-Wilk test. For group comparisons, the Mann-Whitney U test was applied to non-normally distributed variables. Categorical variables were presented as frequencies and percentages, and comparisons were performed using the Pearson chi-square test. When expected cell counts were below 5, the Fisher's exact test or the Fisher-Freeman-Halton exact test was used. A p-value <0.05 was considered statistically significant.

Results

Characteristics of Traumatic Patients and Trauma Etiology

Among the 375 patients included in the study, 254 (67.7%) were male, and the median age was 116.91 months (range:

5-216). The most common causes of trauma were traffic accidents (41.86%), earthquake-related injuries (24.8%), and falls from height (21.34%). Injuries caused by sharp objects such as knives or glass, and crush injuries resulting from heavy blunt objects such as televisions or cabinets, were observed less frequently. The mean PTS value was 9.09±1.51; PTS was less than 9 in 69.3% of cases and 10 or higher in 30.7% of cases. The trauma-related length of stay in the PICU was 6.15±7.34 days, and the mortality was 7.73% (Table 1).

The annual distribution of patients is shown in Figure 1. The sudden increase in the number of cases in 2023 is associated with the February 2023 Türkiye earthquake and with our hospital serving as a central medical facility in the earthquake-affected region.

Intervention and Findings in Patients with Thoracic Trauma

Among the 375 patients followed up for trauma, 29% (n=109) had thoracic trauma. Tube thoracostomy was performed in 53.2% (58/109) of these patients; surgical treatment in 11.9% (13/109); bronchoscopy in 8.26% (9/109); and mechanical ventilation in 33.9% (37/109) (Table 2). The most common complications observed in these patients were pulmonary contusion (59.6%) and PTX (42.2%). The most frequent concomitant injuries among patients with thoracic trauma were head trauma, femur fracture, and laceration of the liver and/or spleen (Table 3).

No significant differences were observed between patients with and without thoracic trauma with respect to age, cause of trauma, or clinical outcomes. A statistically significant difference in length of stay in the PICU was found between patients with and without thoracic injury (p=0.002) (Table 1).

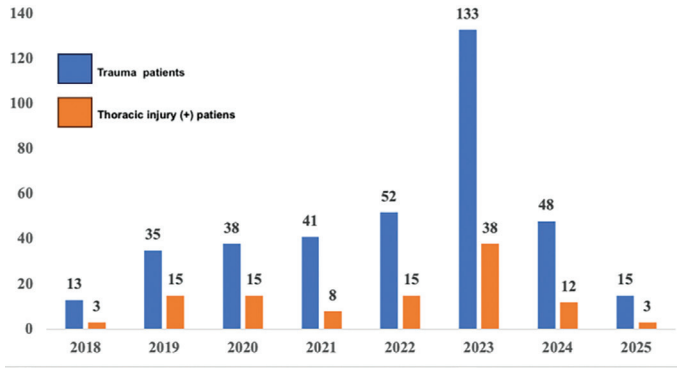

Figure 1. Distribution of trauma and thoracic injury (+) patients by year

Case Reports

Information on five representative patients followed in the PICU for trauma with accompanying thoracic injury is presented in Table 4.

Discussion

Young children are prone to trauma because of a lack of attention, whereas adolescent males are more susceptible because of greater activity and mobility.[5] Similarly, in our study, the mean age of patients was 116.91 months; among patients with thoracic trauma, the median age was 132 (66-190) months, and there was a male predominance of 2:1. In the study by Jung et al.[12] traffic accidents and falls from height were reported as the most frequent causes of thoracic trauma, with the thorax being the third most commonly injured region following head-neck and extremity injuries. In contrast, because of the February 2023 Türkiye earthquake in our region, earthquake-related injuries ranked second and

Table 1. Characteristics of patients

	Trauma patients n=375 (100%)	Thoracic injury (+) patients n=109 (29%)	Thoracic injury (-) patients n=266 (71%)	p-value*
Age (months) Median (IQ1-IQ3)	116.91 (5-216)	132 (66-190)	111 (55.75-174.25)	0.055
Length of stay in PICU (days) median (IQ1-IQ3)	6.15 (1-57)	4 (3-8)	4 (2-6)	**0.002**
	n (%)	**n (%)**	**n (%)**	
Trauma reason				0.082
Traffic accident	157 (41.86)	59 (54.1)	98 (36.84)	
Earthquake-related injury	93 (24.8)	19 (17.4)	74 (27.82)	
Fall from height	80 (21.34)	19 (17.4)	61 (22.93)	
Firearm injury	21 (5.6)	5 (4.6)	16 (6.1)	
Sharp object injury	16 (4.27)	3 (2.8)	13 (4.81)	
Injury with blunt object	8 (2.13)	4 (3.7)	4 (1.5)	
Clinical outcome				0.504
Discharge	346 (92.97)	99 (90.80)	247 (92.90)	
Exitus	29 (7.73)	10 (9.20)	19 (7.10)	

*: Mann-Whitney U test was applied to non-normally distributed variables. Categorical variables were presented as frequencies and percentages, and comparisons were performed using the Pearson chi-square test. When expected cell counts were below 5, the Fisher's exact test or Fisher-Freeman-Halton exact test was used. P<0.05 was considered statistically significant
PICU: Pediatric intensive care unit

Table 2. Interventional procedures of thoracic injury (+) patients

Intervention	n (%)
Surgical treatment Diaphragm repair Pulmonary repair Lung resection Chest wall repair	 4 (3.7) 3 (2.7) 1 (0.9) 5 (4.58)
Tube thoracostomy	58 (53.2)
Bronchoscopy	9 (8.26)
Mechanically ventilated	37 (33.9)

Table 3. Thoracic and extrathoracic injuries of thoracic injury (+) patients

Thoracic injury	n (%)	Extrathoracic injury	n (%)
Pulmonary contusion	65 (59.26)	Head and neck injury	46 (42.2)
Pulmonary laceration	8 (7.4)	Femur fracture	24 (22)
Pneumothorax	46 (42.2)	Humerus fracture	16 (14.6)
Hemopneumothorax	9 (8.2)	Multiple extremity fracture	5 (4.6)
Hemothorax	8 (7.4)	Pelvic fracture	11 (10)
Pneumomediastinum	8 (7.4)	Vertebra fracture	7 (6.4)
Tracheobronchial injury	7 (6.4)	Liver laceration	24 (22)
Diaphragm rupture	4 (3.7)	Splenic laceration	18 (16.5)
Rib fracture	11 (10)	Bladder rupture	6 (5.5)
Clavicula fracture	5 (4.6)	Colon-duodenum rupture	6 (5.5)
Scapula fracture	4 (3.7)	Renal laceration	4 (3.7)
Subcutaneous emphysema	14 (12.8)		
Chest wall laceration	5 (4.6)		

falls from height ranked third. The increase in the number of cases in 2023 was also associated with the earthquake. Despite technological advances and safety measures, traffic accidents remain the leading cause of traumatic injury, while earthquakes cause simultaneous severe injuries in large populations due to widespread destruction. Because of their physiological characteristics, children constitute the group most affected by trauma, and thoracic injuries can be life-threatening in these cases.[13-15] When the same amount of kinetic energy is applied to a child's thoracic wall, the resulting organ damage is more severe than in an adult with greater muscle mass. Because of the elastic structure of the chest wall, organ injury may occur without rib fracture. The mediastinum of children is mobile, allowing positional shifts during compression. While mediastinal shift reduces the risk of injury to the heart and great vessels, it increases the risk of PTX and HTX. Since children have higher metabolic demands and lower pulmonary reserves, rapid decompensation may develop. All these factors require early recognition and prompt intervention in pediatric patients with life-threatening conditions.[2-16]

PTX is a life-threatening condition observed in 40-50% of thoracic trauma cases. X-ray imaging, bedside ultrasonography, and computed tomography (CT) are useful for diagnosis. Treatment involves a comprehensive approach, including close monitoring, oxygen therapy, and tube thoracostomy. The gold-standard treatment is tube thoracostomy. Advanced life support algorithms prioritize tube thoracostomy in traumatic cases due to the risk of tension PTX.[4] HTX is defined as pleural fluid with a hematocrit value equal to or greater than 50% of peripheral blood hematocrit. HTX and hemopneumothorax occur in approximately one-third of thoracic injuries. A

Table 4. Cases followed in PICU due to thoracic trauma

Case	Age*	Trauma reason	Diagnosis	Treatment	Clinical outcome
1	102	Traffic accident	Pediatric surgery: pulmonary contusion, pneumothorax Brain neurosurgery: no pathology Orthopedics: no pathology	- Right tube thoracostomy	Discharge
2	86	Traffic accident	Pediatric surgery: pulmonary contusion, hemopneumothorax Brain surgery: no pathology Orthopedics: femur fracture	- Left tube thoracostomy	Discharge
3	164	Thoracic firearm injury	Pediatric surgery: entry wound on the right scapula, exit wound on the left shoulder, pulmonary contusion: hemopneumothorax Brain surgery: cerebral edema	- Lung and chest wall repair - Left tube thoracostomy	Brain death
4	204	Traffic accident	Pediatric surgery: bronchial injury, pneumothorax Brain surgery: cerebral edema Orthopedics: right tibia and fibula fractures	- Pulmonary resection - Right tube thoracostomy	Brain death
5	187	Cranial firearm injury, fall from height	Pediatric surgery: pulmonary contusion, bilateral pneumothorax, pneumomediastinum, subcutaneous emphysema Brain surgery: displaced fracture, subarachnoid hemorrhage, parenchymal hemorrhage Orthopedics: no pathology	- Bilateral tube thoracostomy - Bronchoscopy	Discharge

*: Months, PICU: Pediatric intensive care unit

significant volume of blood may accumulate in the pleural cavity, leading to hypovolemic shock. In addition, HTX may cause atelectasis and respiratory distress, which is a life-threatening clinical condition. For diagnostic purposes, CT is the gold-standard, whereas ultrasound is the recommended method. The most critical step in the treatment of HTX is the early performance of a tube thoracostomy to prevent hypovolemia and lung compression. Providing analgesia in patients with thoracic trauma is essential. In our unit, paracetamol or pethidine hydrochloride is commonly preferred. During invasive procedures such as tube thoracostomy, wound suturing, or catheter insertion, ketamine is used. After monitoring, oxygenation, and sedation, bedside tube thoracostomy is performed in unstable patients; tube thoracostomy is conducted in the pediatric emergency department. Consequently, tube thoracostomy was required in 53.2% of the patients. Figures 2A and 2B show X-ray images of two patients who underwent tube thoracostomy due to PTX and HTX.

Pulmonary contusion is characterized by alveolar hemorrhage, edema, and inflammation in the absence of pulmonary vascular injury, resulting from transmission of kinetic energy to the lung parenchyma during blunt trauma. It has been reported to occur over a wide range (17-75%) in blunt thoracic trauma. In our study, this rate was found to be 59.26%. The definitive diagnosis is made by CT. Treatment should include monitoring of vital signs, oxygen supplementation, pain control, early mobilization, and chest physiotherapy.[2-17,18]

Pulmonary laceration usually results from penetrating trauma that causes injury to the pulmonary parenchyma. If the laceration extends to the pleura, HTX or PTX may accompany the injury. Tube thoracostomy is recommended as supportive treatment when necessary. Surgical intervention should be considered for patients presenting with hemoptysis or persistent major air leakage.[2] Pulmonary laceration is less common than contusion, but patients suspected of having a laceration should be evaluated early for possible surgical complications. In our study, pulmonary laceration was detected in 7.4% of patients. A patient with a gunshot-induced thoracic injury underwent primary repair of the left lung, chest wall reconstruction, and tube thoracostomy and was followed postoperatively in the PICU (Figure 2C).

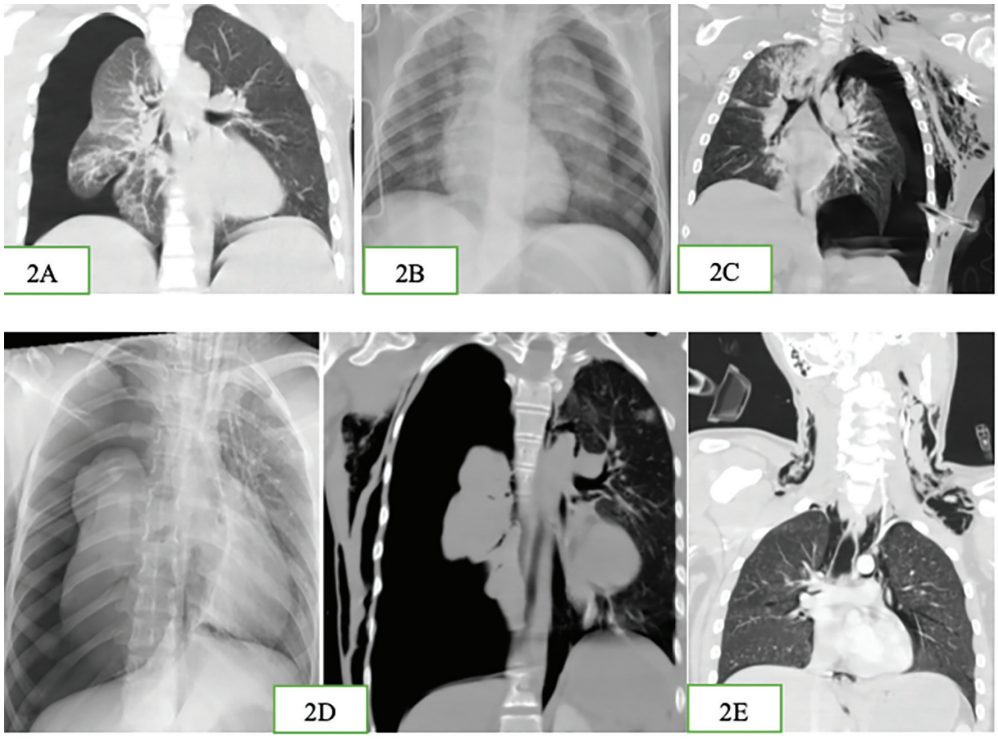

Figure 2. Radiological images of cases. **A)** A right pneumothorax is seen on computed tomography of Case 1. **B)** Left hemopneumothorax is seen on the PA radiograph of Case 2. **C)** Thoracic computed tomography image of Case 3 shows pneumomediastinum, pneumothorax, subcutaneous emphysema, and collapsed lung tissue. The pediatric surgery team performed surgical repair on the patient's left lung and chest wall. **D)** Persistent massive pneumothorax and collapsed lung tissue are seen on PA chest radiography and thoracic computed tomography performed after tube thoracostomy in Case 4. When the patient underwent a thoracotomy performed by the pediatric surgery team, complete separation of the right main bronchus was observed, necessitating a total resection of the right lung. **E)** Thoracic computed tomography shows pneumomediastinum and subcutaneous emphysema. The patient was followed for a displaced occipital fracture, subarachnoid hemorrhage, parenchymal hemorrhage, pulmonary contusion, pneumothorax, pneumomediastinum, and subcutaneous emphysema sustained in a fall that followed a cranial gunshot wound. The patient underwent bilateral tube thoracostomy and bronchoscopy for persistent pneumomediastinum. The tracheobronchial structures were normal. Pulmonary findings resolved during follow-up. The patient was extubated 2 weeks later
PA: Posteroanterior

Tracheobronchial injury refers to damage to the trachea and bronchi (the tracheobronchial tree). Its incidence has been reported as 0.8-5%; however, the true frequency remains uncertain because it is typically observed in patients with severe trauma who often die before hospital admission. Diagnosis is challenging due to coexisting traumatic injuries. The presence of dyspnea, hemoptysis, stridor, subcutaneous or mediastinal emphysema, pneumomediastinum, tension PTX, and massive air leaks should raise suspicion for tracheobronchial injury (Figures 2D and 2E). CT and bronchoscopy are the preferred diagnostic tools.[2-4]

In blunt chest trauma, the factors influencing mortality and morbidity include age, bone fractures, need for mechanical ventilation, preexisting lung disease, head injury, hypotension, and extra-thoracic organ injury. A low Glasgow Coma scale is an important predictor of mortality.[3,5,10] The mortality rate in thoracic trauma is approximately 5%, but when accompanied by injuries to other systems, it rises to 25-40%.[1] In the study by Jung et al.[12] overall trauma mortality was 14.9%, the incidence of thoracic trauma was 12.4%, and thoracic trauma-related mortality was 4.8%. In contrast, in the study by Sweet et al.[3] the incidence of thoracic trauma was 2.4%, with a mortality rate of 5.5%. In our study of 375 patients, overall trauma mortality was 7.73% (29/375); the incidence of thoracic trauma was 29% (109/375); and thoracic trauma-related mortality was 2.7% (10/375). Thoracic trauma was more frequent in our patient group, while mortality was lower than that reported by Jung et al.[12] and similar to Sweet et al.[3] This difference can be attributed to variations in the causes and severity of trauma.

Study Limitations

In addition to being retrospective and single-center, this study's most significant limitation is the exclusion of patients followed in the emergency department and other intensive care units. Due to the chaotic environment following the earthquake and issues with patient identification, patient records may have been missing.

Conclusion

Trauma is the most common emergency encountered by physicians managing critically ill patients. In the aftermath of disasters, many patients must be managed simultaneously. In trauma cases involving thoracic injury, reducing mortality and morbidity depends on prompt identification of the need for appropriate medical and surgical interventions. In the presence of traumatic PTX, HTX, or haemopneumothorax, early tube thoracostomy should be performed if the patient is symptomatic. Pulmonary contusion should be considered in blunt trauma, and pulmonary laceration should be considered in penetrating trauma. PTX and HTX persisting despite tube thoracostomy require surgical intervention. When pneumomediastinum and subcutaneous emphysema are detected, tracheobronchial injury should be suspected.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Ethics Committee for Scientific Research of University of Health Sciences Türkiye, Adana City Training and Research Hospital (approval no: 733, date: 25.09.2025).

Informed Consent: Due to the retrospective design of the study, informed consent was not obtained from the patients' relatives.

Footnotes

Authorship Contributions

Surgical and Medical Practices: İ.A., Z.Ö., C.P., Concept: K.İ., M.D.E., İ.A., Z.Ö., C.P., Design: K.İ., M.D.E., İ.A., Z.Ö., C.P., Data Collection or Processing: K.İ., M.D.E., İ.A., Analysis or Interpretation: K.İ., M.D.E., İ.A., Literature Search: K.İ., M.D.E., İ.A., Writing: K.İ., M.D.E., İ.A., Z.Ö., C.P.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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Research Article / Özgün Araştırma

DOI: 10.4274/cayd.galenos.2026.03030
J Pediatr Emerg Intensive Care Med 2026;13(2):86-94

Evaluation of Patients with Continuous Renal Replacement Therapy in a Pediatric Intensive Care Unit: A Single-center Study

Çocuk Yoğun Bakım Ünitesinde Sürekli Renal Replasman Tedavisi Uygulanan Hastaların Değerlendirilmesi: Tek Merkezli Çalışma

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Abstract

Introduction: This study aimed to evaluate the demographic and epidemiological aspects of patients who underwent continuous renal replacement therapy (CRRT) in a pediatric intensive care unit to determine the appropriate CRRT model and to reveal the factors affecting survival.

Methods: The demographic data of 85 patients who underwent CRRT in the Pediatric Intensive Care Unit of Çukurova University Faculty of Medicine Balcalı Hospital between September 2014 and January 2022 and data from 125 CRRT procedures were recorded and evaluated by statistical analysis.

Results: 52.9% of the patients were female, the mean age was 63.8±67.6 (months), and the mean body weight was 18.9±17.8 kg. The most common, underlying primary disease was nephrological (37.6%). While 88.8% of the applied CRRT procedure was continuous venovenous hemodiafiltration, 11.2% was continuous venovenous hemodialysis. Complications were observed during the procedure in 68% of the patients. In our study, unfractioned heparin was applied to 44.8% of CRRT procedures and citrate to 14.4%. The filter life of the patients treated with heparin was determined to be considerably shorter (p=0.002). It was observed that low pH and HCO_3 values and high lactate level, which are laboratory parameters obtained before CRRT, increased mortality (p=0.001, p=0.047, and p=0.001, respectively).

Conclusion: The success of CRRT treatment was thought to depend on the clinical condition of the patient, the underlying treatable disease, the control of technical problems, and the experience of the teams. In order to support the findings obtained in our study with definitive data, multicenter randomized controlled studies are required.

Keywords: Continuous renal replacement therapy, intensive care, child

Öz

Giriş: Bu çalışmanın amacı, çocuk yoğun bakım ünitesinde sürekli renal replasman tedavisi (CRRT) uygulanan hastaların demografik ve epidemiyolojik özelliklerini değerlendirmek, uygun CRRT modelini belirlemek ve sağkalımı etkileyen faktörleri ortaya koymaktır.

Yöntemler: Eylül 2014-Ocak 2022 tarihleri arasında Çukurova Üniversitesi Tıp Fakültesi Balcalı Hastanesi Çocuk Yoğun Bakım Ünitesi'nde CRRT uygulanan 85 hastaya ait demografik veriler ile toplam 125 CRRT işlemine ait veriler kaydedilmiş ve istatistiksel analizler ile değerlendirilmiştir.

Bulgular: Hastaların %52,9'u kadın olup, ortalama yaş 63,8±67,6 ay, ortalama vücut ağırlığı ise 18,9±17,8 kg idi. En sık altta yatan primer hastalık nefrolojik hastalıklar (%37,6) olarak saptandı. Uygulanan CRRT işlemlerinin %88,8'i sürekli venovenöz hemodiyafiltrasyon, %11,2'si ise sürekli venovenöz hemodiyaliz idi. Hastaların %68'inde işlem sırasında komplikasyon geliştiği gözlendi. Çalışmamızda CRRT işlemlerinin %44,8'inde unfraksiyone heparin, %14,4'ünde ise sitrat antikoagülasyonu kullanıldı. Heparin ile tedavi edilen hastalarda filtre ömrünün anlamlı derecede daha kısa olduğu belirlendi (p=0,002). CRRT öncesinde elde edilen laboratuvar parametrelerinden düşük pH ve HCO_3 değerleri ile yüksek laktat düzeyinin mortaliteyi artırdığı gözlendi (sırasıyla p=0,001, p=0,047 ve p=0,001).

Sonuç: CRRT tedavisinin başarısının; hastanın klinik durumu, altta yatan tedavi edilebilir hastalık, teknik sorunların kontrolü ve ekiplerin deneyimi ile ilişkili olduğu düşünülmektedir. Çalışmamızda elde edilen bulguların kesin verilerle desteklenebilmesi için çok merkezli randomize kontrollü çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Sürekli renal replasman tedavisi, yoğun bakım, çocuk

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Cite this article as: Ekren A, Yıldızdaş D, Horoz ÖÖ, Ekinci F, Yöntem A, et al. Evaluation of patients with continuous renal replacement therapy in a pediatric intensive care unit: a single-center study. J Pediatr Emerg Intensive Care Med. 2026;13(2):86-94

Introduction

Continuous renal replacement therapy (CRRT) has become the method of choice for the treatment of critically ill children with acute kidney injury (AKI) and fluid overload over the past three decades.[1,2] The effectiveness of CRRT has increased over the years because of gradual improvements in treatment modalities and developments in technology that maintain blood flow even in hemodynamically unstable patients. Positive results, compared with more traditional dialysis methods, indicate the safety of CRRT when used in critically ill, hemodynamically unstable children. However, survival among children receiving CRRT has not increased in parallel with advances in technology.

The basic principles of CRRT are similar for adults and children. However, some adaptations need to be made for the application of CRRT to pediatric patients. Extracorporeal blood volume is particularly important for pediatric patients. Prescriptions created for adult patients need to be adapted for pediatric patients to account for their physiological needs. Providing appropriate renal replacement therapy (RRT) for pediatric patients with AKI also includes special considerations not commonly seen in the care of adult patients. The weight of pediatric patients with AKI can range from a 1.5 kg newborn to a 200 kg adult.[3] The indications for CRRT in pediatric patients are similar to those for adults. However, non-renal indications, such as congenital metabolic disorders or post-operative care of an infant with a congenital cardiac anomaly, are special conditions that may require RRT in pediatric patients.[4,5] CRRT has become the RRT modality of choice to support children with critical AKI.[6]

This study aimed to evaluate the demographic and epidemiological characteristics of patients who underwent CRRT in a pediatric intensive care unit to determine the appropriate CRRT model and identify factors affecting survival.

Materials and Methods

In this retrospective study, the demographic data for 85 patients who underwent CRRT in the Pediatric Intensive Care Unit of Çukurova University Faculty of Medicine Balcalı Hospital between September 2014 and January 2022, and data from 125 CRRT procedures were recorded. The necessary permission for the study was obtained from the Ethics Committee of Çukurova University Faculty of Medicine Non-Interventional Clinical Research (approval no: 1, date: 06.12.2019). The ethics committee reviewed our study and waived the need for informed consent because all data and samples were analyzed retrospectively and were collected as part of routine clinical practice, in accordance with current guidelines. Informed consent was not required and therefore not obtained, as the study was conducted retrospectively and involved no direct patient intervention.

Patient data were obtained from the hospital information management system and from patient files. The demographic characteristics of patients, the underlying primary disease, the reason for hospitalization in the pediatric intensive care unit, the duration of hospitalization, the pediatric mortality risk (PRISM-III) and pediatric logistic organ dysfunction (PELOD-II) scores recorded during hospitalization, the number and types of organ failure, the total CRRT duration during pediatric intensive care hospitalization, and the mortality status in the intensive care unit were recorded.

To evaluate CRRT characteristics, the indication for CRRT, the selected CRRT mode, the localization of the vascular pathway, the catheter size, and the anticoagulant method were recorded. CRRT complications, the reason for treatment termination, inotropic support during CRRT, the vasoactive inotrope score, mechanical ventilation, extracorporeal membrane oxygenation (ECMO), erythrocyte, thrombocyte, and fresh frozen plasma (FFP) support were evaluated.

Patients with complete clinical and CRRT procedure records were included in the analysis. Those with missing or incomplete medical files, nursing observation notes, or CRRT monitoring charts—particularly during periods of transition to the digital hospital record system—were excluded.

Values of blood gases, lactate, sodium, potassium, total and ionized calcium, magnesium, phosphorus, blood urea nitrogen (BUN), creatinine, uric acid, hemoglobin, and hematocrit were recorded in the patients before and after CRRT and compared between the pre- and post-treatment periods.

Statistical Analysis

The SPSS 25.0 software package was used for statistical analysis of the data. Categorical measurements were summarized as counts and percentages; continuous measurements were summarized as mean, standard deviation, median, and minimum-maximum. The distributions of continuous measurements between groups were assessed with the Shapiro-Wilk test. A paired-samples t-test was used to compare continuous measurements before and after treatment. An independent-samples t-test was used to compare continuous measurements between groups. Chi-square and Fisher's exact tests were used to compare categorical variables. The statistical significance level was set at 0.05 for all tests.

Results

Among the patients, 52.9% were female, and the mean age was 63.8±67.6 months. The mean body weight of the patients was 18.9±17.8 kg. The mean PRISM-III scores of the

patients were 11.5±9.2, while the mean PELOD-II scores were 19.6±13.6. The most frequently affected organ systems were the renal system (69.4%), the respiratory system (55.3%), and the cardiovascular system (25.9%). The mean length of stay in the intensive care unit was 11±13.2 days, while the mean hospital stay was 28.2±23.7 days. 17.6% of patients died during their intensive care stay. The patients' demographic and hospitalization data are presented in Table 1.

Table 1. Demographic data and hospitalization data

Parameters	All patients (n=85)
Gender, n (%)	
Male	40 (47.1%)
Female	45 (52.9%)
Age (month)	
Mean ± standard deviation	63.8±67.6
Median	28
Minimum-maximum	1-210
Body weight (kg)	
Mean ± standard deviation	18.9±17.8
Median	11
Minimum-maximum	3.5-90
Body weight groups, n (%)	
<10 kg	39 (45.9%)
10-20 kg	21 (2.7%)
20-50 kg	17 (20%)
>50 kg	8 (9.4%)
Admission PRISM-III score	
Mean ± standard deviation	11.5±9.2
Median	8
Minimum-maximum	1-44
Admission PELOD-II score	
Mean ± standard deviation	19.6±13.6
Median	12
Minimum-maximum	1-52
Number of organ failures (n)	
Mean ± standard deviation	2±1.1
Median	2
Minimum-maximum	1-6
Affected organ system, n (%)	
Respiratory	47 (55.3%)
Cardiovascular	22 (25.9%)
Renal	59 (69.4%)
Neurological	17 (20%)
Hematological	9 (10.6%)
Hepatic	11 (12.9%)
Intensive care hospital stay (days)	
Mean ± standard deviation	11±13.2
Median	6
Minimum-maximum	1-79
Length of hospital stay (days)	
Mean ± standard deviation	28.2±23.7
Median	20
Mean ± standard deviation	3-110
Total CRRT time (hours) during intensive care stay	
Mean ± standard deviation	42.1±47
Median	23
Minimum-maximum	3-237
Mortality in intensive care, n (%)	
No	70 (82.4%)
Yes	15 (17.6%)

PRISM-III: Pediatric mortality risk score, PELOD-II: Pediatric logistic organ dysfunction score, CRRT: Continuous renal replacement therapy

Before the start of CRRT, double-lumen catheters were placed by intensive care unit specialists. Ultrasound was used during catheter placement. Regarding CRRT access routes, 74.4% of the patients had a right jugular dialysis catheter, 10.4% had a left jugular catheter, 8.8% had a right subclavian catheter, and 6.4% had a right femoral catheter. The most commonly used dialysis catheter sizes were 7 French (F) (48%), 9F (17.6%), and 8F (16%) (Table 2).

The distribution of indications for CRRT showed that most patients initiated CRRT because of fluid overload (70.4%) or metabolic disease/severe metabolic acidosis (24%). The mean fluid load of patients who underwent CRRT for fluid overload was 9.8±4.2%. Considering the CRRT modalities applied, 88.8% of the procedures were continuous venovenous hemodiafiltration (CVVHDF), while 11.2% were continuous venovenous hemodialysis (CVVHD). In clinical practice, CVVHDF was the preferred initial modality for patients with fluid overload and metabolic indications, whereas CVVHD was reserved mainly for selected cases with predominant

Table 2. Catheter data

Parameters	All procedures (n=125)
Dialysis catheter site, n (%)	
Right jugular	93 (74.4%)
Left jugular	13 (10.4%)
Right subclavian	11 (8.8%)
Right femoral	8 (6.4%)
Dialysis catheter size, n (%)	
7F	58 (48%)
8F	20 (16%)
9F	22 (17.6%)
10F	11 (8.8%)
12F	12 (9.6%)

F: French size

azotemia or electrolyte imbalances. The mean blood flow rate was 5.7±2.2 mL/kg/min, and the mean total dialysis dose was 2396.4±679 mL/1.73 m^2/hour. The treatment data obtained from 125 CRRT procedures are summarized in Table 3.

When the laboratory parameters obtained before and after patient CRRT application were compared, it was observed that there was a notable change in the mean pH, base deficit, and HCO_3 values in the post-treatment period (p=0.001). There was no statistically significant change in lactate values before and after treatment (p=0.173). A distinct increase was observed in the mean hemoglobin values of the patients during the post-treatment period (p=0.001). Among the biochemical parameters, BUN, creatinine, and uric acid decreased markedly in the post-treatment period (p=0.001). Serum potassium, magnesium, and phosphorus levels decreased significantly in the post-treatment period (p=0.001, p=0.015, and p=0.001, respectively). Although sodium and calcium values decreased in the post-treatment period, the differences between the two periods were not statistically significant (p>0.05) (Table 4).

Complications were observed during the procedure in 68% of the patients. The most common were metabolic imbalance (47.2%), coagulation in the circuit (27.2%), and hypotension (14.4%). Among patients with metabolic imbalance,

Table 3. CRRT indications and treatment settings

Parameters	All procedures (n=125)
CRRT indication, n (%)	
Fluid load (not responding to medical treatment)	88 (70.4%)
Severe azotemia and symptomatic uremia	3 (2.4%)
Metabolic disease/severe metabolic acidosis	30 (24%)
Electrolyte disorder	2 (1.6%)
Drug intoxication	2 (1.6%)
Fluid load at initiation of CRRT (%)	
Mean ± standard deviation	9.8±4.2
Median	10
Minimum-maximum	2-25
Mode of CRRT, n (%)	
CVVHDF	111 (88.8%)
CVVHD	14 (11.2%)
Blood flow speed (mL/kg/min)	
Mean ± standard deviation	5.7±2.2
Median	5.81
Minimum-maximum	1.47-11.43
Total dialysis dose (mL/1.73 m^2)	
Mean ± standard deviation	2396.4±679
Median	2169.51
Minimum-maximum	1251.94-5476.56

CRRT: Continuous renal replacement therapy, CVVHDF: Continuous venovenous hemodiafiltration, CVVHD: Continuous venovenous hemodialysis

Table 4. Comparison of blood gas, biochemistry, hemogram, and electrolyte values with the pre- and post-treatment period of CRRT

Parameters	Before CRRT	After CRRT	p-values
pH			
Mean ± standard deviation	7.29±0.09	7.35±0.08	**0.001**
Median	7.3	7.36	
Minimum-maximum	7.05-7.51	6.9-7.5	
Base deficit (mEq/L)			
Mean ± standard deviation	-5.7±5.5	-2.4±3.7	**0.001**
Median	-4.9	-2.3	
Minimum-maximum	-23.2-4.7	-17-7	
HCO_3 (mEq/L)			
Mean ± standard deviation	18.8±4.6	21.7±3.4	**0.001**
Median	19.5	21.7	
Minimum-maximum	3-28	9-30.5	
Lactate (mmol/L)			
Mean ± standard deviation	2.6±2.9	2.3±3.3	0.173
Median	1.6	1.2	
Minimum-maximum	0.3-22	0.3-21	
Blood urea nitrogen (mg/dL)			
Mean ± standard deviation	45.1±35.1	26.2±21.1	**0.001**
Median	38	23.4	
Minimum-maximum	2.3-151.2	1-109.4	
Creatinine (mg/dL)			
Mean ± standard deviation	2.6±2.5	1.6±1.6	**0.001**
Median	1.95	1.2	
Minimum-maximum	0.16-12.14	0.04-11.3	
Uric acid (mg/dL)			
Mean ± standard deviation	7.6±4.8	4.5±2.6	**0.001**
Median	6.5	4.05	
Minimum-maximum	0.6-24	0.8-18	
Hemoglobin (g/L)			
Mean ± standard deviation	8.8±1.8	9.2±2	**0.049**
Median	8.5	9	
Minimum-maximum	5.4-14.8	6.1-22.5	
Sodium (mmol/L)			
Mean ± standard deviation	142.3±8.5	141.8±14.2	0.644
Median	141	142	
Minimum-maximum	118-178	120-162	
Potassium (mmol/L)			
Mean ± standard deviation	3.5±1	3.1±0.7	**0.001**
Median	3.2	3	
Minimum-maximum	1.7-7.2	1.7-5.5	
Total calcium (mg/dL)			
Mean ± standard deviation	9.3±1.1	9.1±1.2	0.167
Median	9.4	9.14	
Minimum-maximum	6.1-13.9	5.2-13.71	

Table 4. Continued

Parameters	Before CRRT	After CRRT	p-values
Ionized calcium (mg/dL)			
Mean ± standard deviation	1±0.2	1±0.2	0.660
Median	0.98	0.98	
Minimum-maximum	0.44-1.5	0.56-1.69	
Magnesium (mg/dL)			
Mean ± standard deviation	2.2±0.9	2±0.7	**0.015**
Median	1.97	1.82	
Minimum-maximum	0.94-7.9	1.05-6.7	
Phosphorus (mg/dL)			
Mean ± standard deviation	5.1±2.6	3.6±1.5	**0.001**
Median	4.75	3.35	
Minimum-maximum	0.62-12.4	1.1-8.1	

CRRT: Continuous renal replacement therapy

hypokalemia developed in 50.9%, hypocalcemia in 49.2%, and hypophosphatemia in 16.9%. The majority of patient treatments were terminated for completion (60.8%) and for coagulation in the circuit (30.4%) (Table 5).

No statistically significant difference in complications was observed between patients treated with heparin and those treated with citrate (p>0.05). The filter life was significantly shorter in patients treated with heparin (p=0.002) (Table 6).

Table 5. Complications, metabolic imbalance, and reasons for termination of treatment

Parameters	All procedures
Complication, n (%)	
None	40 (32%)
Bleeding	1 (0.8%)
Coagulation in the circuit	34 (27.2%)
Metabolic imbalance	59 (47.2%)
Hypotension	18 (14.4%)
Hypothermia	5 (4%)
Other complications	2 (1.6%)
Metabolic imbalance, n (%)	
Metabolic acidosis	3 (5.1%)
Hypocalcemia	29 (49.2%)
Hypokalemia	30 (50.9%)
Hypernatremia	2 (3.4%)
Hypophosphatemia	10 (16.9%)
Hypomagnesemia	5 (8.5%)
Reason for termination of treatment, n (%)	
Completion of treatment	76 (60.8%)
Coagulation in the circuit	38 (30.4%)
Catheter dysfunction	5 (4.0%)
Technical problems	1 (0.8%)
Other reasons	5 (4.0%)

When the applied treatments were examined, the rate of inotropic administration was 37.6%. The highest vasoactive-inotropic score was found to be 34.1±27.3 on average. The proportion of patients who underwent mechanical ventilation was 51.2%. The proportion of patients who underwent ECMO was 4%. 74.4% of the patients received erythrocyte suspension support, 38.4% received thrombocyte support, and 27.2% received FFP support (Table 7).

Table 6. Complications and filter life in patients treated with heparin and citrate

Parameters	Heparin (n=56)	Sitrat (n=18)	p-values
Complication, n (%)			
None	26 (46.4%)	5 (27.8%)	0.163
Bleeding	1 (1.8%)	0 (0%)	1.000
Coagulation in the circuit	12 (21.4%)	4 (22.2%)	1.000
Metabolic imbalance	23 (41.1%)	9 (50%)	0.506
Hypotension	6 (10.7%)	3 (16.7%)	0.679
Hypothermia	6 (10.7%)	3 (16.7%)	0.145
Filter life (hours)			
Mean ± standard deviation	20.6±25.7	35.8±20.1	**0.002**
Median	13	38	
Minimum-maximum	4-140	7-76	

Table 7. Applied treatments

Parameters	All procedures (n=125)
Inotropic support, n (%)	
No	78 (62.4%)
Yes	47 (37.6%)
Vasoactive inotrope score	
Mean ± standard deviation	34.1±27.3
Median	30
Minimum-maximum	1-117
Mechanical ventilation, n (%)	
No	61 (48.8%)
Non-invasive	4 (3.2%)
İnvasive	60 (48%)
Extracorporeal membrane oxygenation, n (%)	
No	120 (96%)
Yes	5 (4%)
Erythrocyte suspension support, n (%)	
No	32 (25.6%)
Yes	93 (74.4%)
Platelet support, n (%)	
No	77 (61.6%)
Yes	48 (38.4%)
Fresh frozen plasma supplement, n (%)	
No	91 (72.8%)
Yes	34 (27.2%)

Discussion

CRRT is a life-saving treatment that provides appropriate fluid management and removal of toxic substances and metabolites, especially in the care of critically ill children with AKI. CRRT has been used in pediatric patients for nearly 30 years. These new treatment options, which are under development, are also being applied in our country, but data on these applications in pediatric patients are limited both worldwide and nationally.

Patients undergoing CRRT require a vascular access route established via dialysis catheters. In the study by Symons et al.[7], of 344 patients who underwent CRRT, 73% had a femoral catheter, 16% an internal jugular catheter, and 9% a subclavian catheter. Hackbarth et al.[8] applied femoral catheters to 69% of 376 pediatric patients, internal jugular catheters to 16%, and subclavian catheters to 8%. The most common catheter sizes were 11.5 (18.9%), 8 (17.3%), and 12.5 (17%), respectively. In the study by Erkol Tuncer et al.[9], 50% of the patients had a jugular vein catheter, 36% a femoral vein catheter, and 12% a subclavian vein catheter. When we examined the dialysis catheter sites applied to the patients in our study, the most common sites for catheterization were right jugular (74.4%), left jugular (10.4%), right subclavian (8.8%), and right femoral (6.4%). The most commonly used dialysis catheter sizes were 7F (48%), 9F (17.6%), and 8F (16%).

Fluid load is one of the most common CRRT indications.[10] Flores et al.[11] found that the fluid loads of patients who died and survived were similar in pediatric patients who underwent CRRT. In this study, the mean fluid load of patients initiated on CRRT for fluid overload was approximately 12%. The study indicates that there was no relationship between mortality and fluid load.[11] In the study by Sutherland et al.[12], it was shown that patients with less fluid load before CRRT had a relatively low mortality in the other group. In our study, the mean fluid load of the patients who started CRRT with fluid load was 9.8±4.2%. The literature reports conflicting results regarding the effect of fluid load on mortality. Although some studies show that fluid load affects mortality, others, including ours, indicate that it does not.

Studies on CRRT modes for use in children are ongoing. In the study by Symons et al.[7], it was observed that 48% of the patients were treated with CVVHD, 30% with CVVHDF, and 21% with CVVHF. In a different study conducted on 376 patients, 46% of the patients were treated with CVVHD, 26% with CVVHF, and 24% with CVVHDF.[8] In the study by Askenazi al.[13], CVVHD was applied to 59.5% of the patients. In the same study, the rate of application of CVVHF was 17.9%, while the rate of application of CVVHDF was 22.6%.[13] While 88.8% of the procedures evaluated in our study were CVVHDF, 11.2% were CVVHD.

Complications were observed during 68% of CRRT procedures evaluated in our study. The most common complications were metabolic imbalance (47.2%), coagulation in the circuit (27.2%), and hypotension (14.4%). 50.9% of patients with metabolic imbalances developed hypokalemia, 49.2% hypocalcemia, and 16.9% hypophosphatemia. Schiffl[14] demonstrated that high flow rates cause more hypotension, hypokalemia and hypophosphatemia. Many large-scale studies show that CRRT patients frequently develop hypophosphatemia, hypokalemia, hypocalcemia, and hypomagnesemia.[15-18] In the study by Finkel and Podoll[19] it was shown that the most common complications were bleeding, infection, venous thrombosis, hypothermia, hypotension, and metabolic imbalances. Erkol Tuncer et al.[9] determined that 56% of the patients developed hypotension, 44% hypophosphatemia, 38% hypothermia, 32% hypokalemia, 22% bleeding, and 20% hypovolemia.

Critically ill pediatric patients receiving CRRT frequently require concurrent intensive care support, including vasoactive agents and mechanical ventilation, primarily due to underlying hemodynamic instability and multiorgan dysfunction rather than CRRT itself. Therefore, pediatric CRRT practice necessitates close hemodynamic monitoring and individualized treatment prescriptions to optimize efficacy and minimize procedure-related complications.[20] Additional treatments may be required for patients receiving CRRT. Symons et al.[7] showed that two-thirds of the patients who underwent CRRT received vasopressor therapy. In the study by Askenazi al.[13], the use of vasopressors in patients who died was 79%, while it was 64% in patients who survived, but there was no statistically significant difference between the two groups. In the study by Hayes et al.[21], the need for vasopressors in children who underwent CRRT was found to be 73.7%. Aslan et al.[10] reported a mean vasoactive inotrope score of 24. In addition, the rate of mechanical ventilation was found to be 65.4% in this study. Among the treatments applied in our study, inotropic administration occurred at a rate of 37.6%. The highest vasoactive inotrope score was found to be 34.1±27.3 on average. The rate of patients who underwent mechanical ventilation was 51.2%.

Anticoagulation plays a critical role in CRRT. In a study conducted in the United States, it was observed that 7% of the patients were not treated with anticoagulation, 56% of the patients were treated with citrate, and 37% with classical heparin.[7] Brophy et al.[22] compared anticoagulation methods in patients who underwent multicenter CRRT. Although a slight decrease was detected in the filter life of the patients in whom heparin was used among the anticoagulation methods, no statistically significant difference in filter life was observed between the two groups. In the study by Sık et al.[23] in which heparin was administered to 26 patients and coagulation with citrate during the CRRT procedure to 19 patients, it was determined

that the filter life of the patients who were administered citrate was notably longer than the patients who received heparin. In addition, no distinctive relationship was found between anticoagulation and mortality.[23] Anticoagulation was not applied in 40.8% of CRRT procedures in our study; classical heparin was applied in 44.8%, and citrate in 14.4%. No statistically significant difference in complications between patients treated with heparin and those treated with citrate was observed. The filter life of patients who received heparin was significantly shorter (p=0.002). Studies conducted in the general pediatric population indicate a relationship between citrate, one of the anticoagulation methods, and filter life.[24,25]

One measure of success for CRRT is its effect on mortality. Symons et al.[7] found the mortality rate to be 42%. This study also examined the factors affecting mortality. According to this evaluation, mortality rates increase in patients under 10 kg, under 1 year of age, and with a PRISM-II score above 10.[7] In the study by Askenazi et al.[13], the mortality rate was 57% in children under 10 kg and treated with CRRT, while it was 36% in children over 10 kg. This suggests that the child's body weight may affect mortality. Erkol Tuncer et al.[9] found the mortality rate to be 58% in patients who underwent CRRT, and patients with high urine output and low potassium levels had higher survival rates. Many other studies in the literature specify that mortality in pediatric patients undergoing CRRT varies between 30% and 70%.[26-28] Duyu and Turkozkan[29] found the mortality rate to be 29.7%. Among the factors affecting mortality in pediatric patients who underwent CRRT were underlying primary disease, multi-organ failure, low urine output, the need for mechanical ventilation, and the need for vasopressors. In our study, the mortality rate was 17.6%, and there was no meaningful relationship between mortality and CRRT. The overall mortality rate in our cohort was 17.6%, which is lower than the rates reported in many previous pediatric CRRT studies, where mortality has ranged from 30% to 70%. This relatively low mortality rate may be explained by several factors, including the early initiation of CRRT, a high proportion of patients with potentially reversible renal conditions, lower rates of ECMO support, and the accumulated experience of a specialized multidisciplinary intensive care team. These findings suggest that outcomes of CRRT may be strongly influenced by patient selection and center-specific expertise rather than the CRRT modality alone.

Study Limitations

This study has several important limitations that should be considered when interpreting the results. First, the retrospective, single-center design limits the generalizability of our findings to other pediatric intensive care units with different patient profiles, treatment protocols, and levels of experience with CRRT. Second, although the overall sample size was acceptable for a single-center study, some subgroups—particularly patients receiving citrate anticoagulation—were relatively small, which may have reduced the statistical power to detect differences in complications and outcomes between anticoagulation strategies. Third, due to the retrospective nature of data collection, the timing of CRRT initiation, fluid overload trajectories, and clinical decision-making processes could not be fully standardized or analyzed in detail. Fourth, although several laboratory parameters obtained before CRRT initiation were associated with mortality, comprehensive multivariable analyses were limited, and residual confounding by disease severity, organ dysfunction, and supportive therapies cannot be excluded. Another limitation of the study, in terms of statistical analysis, was that no multivariable regression analysis was performed because the limited number of mortality events in our cohort could have resulted in model overfitting and unreliable estimates. Therefore, odds ratios with 95% confidence intervals could not be reported. Finally, long-term renal outcomes and post-intensive care follow-up data were unavailable, preventing assessment of renal recovery and long-term morbidity. Despite these limitations, our study provides valuable real-world data on CRRT practices and outcomes in a pediatric intensive care unit and contributes to the limited body of national and international literature on this subject.

CRRT is a life-saving method in children with AKI and fluid overload. The success of this treatment depends on the clinical condition of the patient, the underlying treatable disease, the management of technical problems, and the teams' experience. CRRT is an important extracorporeal treatment and life-saving procedure in intensive care units. To confirm the findings of our study, multicenter randomized controlled trials are required.

Conclusion

CRRT remains a vital supportive therapy for critically ill children with AKI and fluid overload. While technological advances have improved the feasibility and safety of CRRT, patient-related factors and center experience continue to play a major role in determining outcomes. Multicenter prospective studies are needed to further clarify optimal timing, dosing, and anticoagulation strategies in pediatric CRRT.

Ethics

Ethics Committee Approval: The necessary permission for the study was obtained from the Ethics Committee of Çukurova University Faculty of Medicine Non-Interventional Clinical Research (approval no: 1, date: 06.12.2019).

Informed Consent: Informed consent was not required and therefore not obtained, as the study was conducted retrospectively and involved no direct patient intervention.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.E., A.Y., Concept: D.Y., Ö.Ö.H., A.K.B., Design: D.Y., Ö.Ö.H., A.K.B., Data Collection or Processing: A.E., A.Y., Analysis or Interpretation: D.Y., F.E., A.Y., A.K.B., Literature Search: A.E., A.Y., Writing: A.E.

Conflict of Interest: No conflict of interest was declared by the authors. One of the authors of this article (D.Y.) is a member of the Editorial Board of this journal. He had no involvement in the peer-review process or editorial decision regarding this manuscript. The peer-review process and editorial decision were handled independently by another editor.

Financial Disclosure: The authors declared that this study received no financial support.

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Research Article / Özgün Araştırma

DOI: 10.4274/cayd.galenos.2026.48039
J Pediatr Emerg Intensive Care Med 2026;13(2):95-100

The Use of Methylene Blue in Children with Catecholamine-resistant Shock: A Retrospective Case Series

Katekolamin Dirençli Şok Tanılı Çocuklarda Metilen Mavisi Kullanımı: Retrospektif Olgu Serisi

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Abstract

Introduction: Shock is a common and life-threatening condition in pediatric intensive care units (PICUs). In catecholamine-resistant shock, current guidelines suggest adjunctive therapies such as hydrocortisone, vasopressin, angiotensin II, or extracorporeal membrane oxygenation (ECMO). Methylene blue (MB) has emerged as a potential alternative or adjunct therapy. We report our clinical experience administering MB to children who had refractory shock unresponsive to standard inotropes and vasopressors.

Methods: We retrospectively reviewed children who were treated with MB between March and November 2023 at a tertiary PICU. Pre- and post-MB variables included vasoactive-inotropic score (VIS), systolic blood pressure (SBP), vasopressor requirements, concurrent continuous renal replacement therapy/ECMO use, and mortality. Hemodynamic parameters were evaluated before MB administration and up to 24 hours thereafter.

Results: Ten patients were included (mean age 9.4 years; 70% with chronic comorbidities). Baseline VIS was 116.4±90.5 and SBP was 81.3±19 mmHg. At 24 hours after MB administration, VIS decreased to 109.9±74.6 and SBP increased to 96.5±18.2 mmHg, corresponding to an average absolute change of -6.5 points in VIS and +15 mmHg in SBP. Hemodynamic responses were heterogeneous: VIS decreased in five patients, remained unchanged in two, and increased in three, while SBP improved in all patients. No MB-related adverse effects were observed. Overall survival to hospital discharge was 10%.

Conclusion: In children with catecholamine-resistant shock, MB administration was associated with short-term improvement in blood pressure, although the reduction in vasoactive burden was inconsistent and mortality remained high. Larger prospective studies are needed to define the optimal timing, dosing, safety, and efficacy of MB in pediatric vasodilatory shock.

Keywords: Catecholamine-resistant shock, methylene blue, pediatric intensive care, septic shock, vasoactive-inotropic score, sepsis

Öz

Giriş: Şok, çocuk yoğun bakım ünitelerinde sık görülen ve yaşamı tehdit eden bir tablodur. Katekolamin dirençli şokta kılavuzlar hidrokortizon, vazopressin, anjiyotensin II veya ekstrakorporeal membran oksijenizasyonu (ECMO) kullanımını önermektedir. Metilen mavisi (MM), potansiyel bir ek tedavi seçeneğidir. Bu çalışmada, standart inotrop ve vazopressör tedavilere yanıtsız, refrakter şoklu çocuklarda MM kullanımına ilişkin deneyimimizi sunuyoruz.

Yöntemler: Mart-Kasım 2023 tarihleri arasında MM ile tedavi edilen çocuklar geriye dönük olarak incelendi. MM uygulaması öncesi ve sonrasında değerlendirilen değişkenler; vasoaktif-inotropik skor (VIS), sistolik kan basıncı (SKB), inotrop/vazopressör dozları ve süreleri, eşzamanlı sürekli renal replasman tedavisi/ECMO uygulamaları ve mortalite olarak belirlendi.

Bulgular: Çalışmaya on hasta dahil edildi (ortalama yaş: 9,4 yıl; %70'inde kronik komorbidite mevcuttu). Başlangıçta VIS 116,4±90,5 ve SKB 81,3±19 mmHg idi. MM uygulamasından 24 saat sonra VIS 109,9±74,6 ve SKB 96,5±18,2 mmHg olarak saptandı. Bu değerler, VIS'te yaklaşık %6,5'lik bir azalma ve SKB'de yaklaşık 15 mmHg'lik bir artışa karşılık gelmekteydi. Hemodinamik yanıtlar heterojen bulundu: VIS beş hastada azaldı, iki hastada değişmedi, üç hastada arttı; SKB ise tüm hastalarda yükseldi. MM'ye bağlı herhangi bir advers etki gözlenmedi. Yalnızca bir hasta taburculuğa kadar sağ kaldı.

Sonuç: Katekolamin dirençli pediatrik şokta MM, kan basıncında düzelme ve inotrop/vazopressör ihtiyacında azalma ile ilişkili bulundu ancak sağkalım oranı düşük saptandı. Septik/vasodilatör şokta MM'nin optimal kullanım zamanı, dozu, güvenilirliği ve etkinliğinin belirlenmesi için daha geniş, prospektif çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Katekolamin dirençli şok, metilen mavisi, çocuk yoğun bakım, septik şok, vazoaktif-inotropik skor, sepsis

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Received/Geliş Tarihi: 29.09.2025 **Accepted/Kabul Tarihi:** 16.02.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Emer Dilaver D, Havan M, Uçmak H, Bayramov B, Eyduran E, et al. The use of methylene blue in children with catecholamine-resistant shock: a retrospective case series. J Pediatr Emerg Intensive Care Med. 2026;13(2):95-100

Introduction

Shock is a life-threatening syndrome of acute circulatory failure that results in inadequate oxygen delivery to tissues. It affects nearly one-third of patients admitted to intensive care units and is associated with high mortality.[1-4] Four major types of shock—distributive, hypovolemic, cardiogenic, and obstructive—may occur alone or in combination.[4,5] Distributive shock, most commonly due to sepsis, predominates in pediatric intensive care units (PICUs). Early recognition and stabilization, including airway, breathing, and circulation assessment, prompt antibiotic therapy, intravenous fluid resuscitation, and initiation of vasopressors when indicated, remain the standard of care.[6]

Despite these measures, a subset of patients develops catecholamine-resistant shock, in which hemodynamic stability cannot be achieved even with escalating doses of conventional vasopressors. Because prolonged exposure to high-dose catecholamines is associated with significant adverse effects, interest has grown in alternative or adjunctive therapies aimed at improving vascular responsiveness.[7,8]

Methylene blue (MB), a heterocyclic aromatic compound, interferes with nitric oxide-dependent signaling pathways by inhibiting soluble guanylate cyclase (sGC), thereby reducing cyclic guanosine monophosphate production and attenuating pathological vasodilation.[9,10] In addition, MB inhibits inducible nitric oxide synthase and scavenges nitric oxide, typically producing measurable hemodynamic effects within 30-60 minutes of intravenous administration.[11-13] Because it is inexpensive, widely available, and generally well tolerated, MB has been proposed as a adjunctive therapy in catecholamine-resistant shock. However, pediatric data remain limited, and its role in routine clinical practice has not been clearly defined.[14,15]

This study aimed to evaluate our clinical experience with MB administration in critically ill children with catecholamine-resistant shock, focusing on short-term hemodynamic effects and clinical outcomes in a highly selected, severely ill patient population.

Materials and Methods

This retrospective observational study was conducted in the PICU of Ankara University between March and November 2023. Children with catecholamine-resistant shock who received MB were included. Demographic and clinical data, including age, sex, underlying conditions, inotrope and vasopressor dosages, MB administration details (loading and maintenance doses, duration), and concurrent therapies were recorded.

Catecholamine-resistant shock was defined as persistent hypotension and/or clinical signs of inadequate tissue perfusion despite adequate fluid resuscitation and treatment with vasoactive agents. Persistent catecholamine-resistant shock was operationally defined as ongoing hemodynamic instability despite the administration of two or more vasoactive agents at escalating doses. In our clinical practice, MB administration was considered when high-dose vasoactive support was required, typically corresponding to a vasoactive-inotropic score (VIS) greater than 30, despite optimization of conventional therapies.[16,17]

The VIS and systolic blood pressure (SBP) were documented before MB initiation and at 4, 8, 12, and 24 hours post-treatment. Mortality outcomes were recorded. Disease severity was assessed using the pediatric risk of mortality III (PRISM III) and pediatric logistic organ dysfunction (PELOD) scores.[18-23] The VIS was calculated as follows: VIS=dopamine (μg/kg/min)+dobutamine(μg/kg/min)+100×epinephrine (μg/kg/min)+10×milrinone (μg/kg/min)+10.000×vasopressin (U/kg/min)+100×norepinephrine (μg/kg/min).

Patients who received continuous renal replacement therapy (CRRT) or extracorporeal membrane oxygenation (ECMO) during their PICU stay were also evaluated.[24-26]

Blood pressure measurements were obtained as part of routine clinical monitoring; however, the use of invasive versus non-invasive measurement methods was not standardized across patients and was not consistently documented. Diastolic blood pressure and mean arterial pressure values were not systematically available for all patients and were therefore not included in the analysis.

Ethical Considerations

The study protocol was approved by the Ankara University Human Research Ethics Committee (approval no: I04-406-24, date: 11.06.2024). Written informed consent for treatment and data use was obtained from the families of all participants.

Statistical Analysis

Analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Continuous variables were expressed as mean ± standard deviation and/or median with interquartile range, as appropriate. Changes in VIS and SBP before and after MB were analyzed using the Wilcoxon signed-rank test, and time-dependent variations at 0, 4, 8, 12, and 24 h were analyzed using the Friedman test with Dunn-Bonferroni correction. Correlations between MB dose, duration, and hemodynamic changes were examined using Spearman's rho. A two-sided $p<0.05$ was considered statistically significant.

Results

Ten children with catecholamine-resistant shock received MB therapy during the study period. Seven patients (70%) were female; the mean age was 9.4 years (range: 3 months-19 years). Most patients (70%) had chronic comorbidities, including bone marrow transplantation, neuromuscular disease with multiple organ dysfunction syndrome, liver transplantation, cystic fibrosis, cerebral palsy, and severe congenital or acquired infections. Baseline clinical characteristics, treatments, and outcomes are summarized in Table 1; mean values are presented in Table 2.

At PICU admission, the mean PRISM III score was 9.0±3.3, and the mean PELOD score was 10.6±5.9, indicating high disease severity. All patients were receiving multiple vasopressors, including norepinephrine, epinephrine, dopamine, and hydrocortisone before MB initiation. The mean baseline VIS was 116.4±90.5, and the mean SBP was 81.3±19.0 mmHg.

Following MB administration, SBP demonstrated a consistent upward trend over the 24-hour observation period, whereas changes in VIS were variable. At 24 hours post-treatment, the mean VIS decreased to 109.9±75.8, corresponding to a mean relative reduction of 6.5%, while mean SBP increased to 96.5±17.3 mmHg, representing a mean relative increase of 18.7%. Statistical testing demonstrated a significant increase in SBP (Wilcoxon signed-rank test, Z=-2.03, p=0.04), whereas the change in VIS did not reach statistical significance (Z=-1.06, p=0.29). A time-series analysis using the Friedman test showed a significant rise in SBP across time points [$\chi^2(4)=9.6$, p=0.048], whereas variations in VIS were not significant [$\chi^2(4)=5.3$, p=0.26].

Individual hemodynamic responses varied: VIS decreased in 5 patients (50%), remained unchanged in 2 patients (20%), and increased in 3 patients (30%). However, SBP improved in all patients, with the greatest relative increase (+142.8%) observed in a patient with amlodipine intoxication. No MB-related adverse effects (e.g., hemolysis, serotonin syndrome, methemoglobinemia) were observed.

The duration of MB therapy ranged from 1 to 6 days (mean 2.6±1.4). A loading dose (1-2 mg/kg) was administered to 6 patients, followed by a continuous infusion at 0.25-1 mg/kg/h. Six patients (60%) underwent CRRT, and four (40%)

Table 1. Clinical characteristics, therapies, and outcomes of patients receiving methylene blue (MB)

Patient no	Age/sex	Primary diagnosis	PRISM III	PELOD	Pre-MB VIS	Steroid	Pre-MB SBP (mmHg)	ECMO	CRRT	MB dose	Duration (days)	Post-MB VIS	Post-MB SBP (mmHg)	Adverse effects	Outcome
1	11 y, F	BMT and septic shock	11	22	80	Yes	102	Yes	Yes	LD 1 mg/kg+MD 0.25 mg/kg/h	6	30	112	None	Died (day 1)
2	17 y, M	Septic shock, MODS	8	12	35	Yes	67	Yes	Yes	MD 1 mg/kg/h	1	35	72	None	Died (day 1)
3	17 y, M	Crush syndrome	8	3	90	Yes	56	No	Yes	MD 0.5 mg/kg/h	1	30	136	None	Died (day 20)
4	3 m, F	Atypical teratoid rhabdoid tumor	8	12	216	Yes	72	No	No	MD 1 mg/kg/h	1	216	78	None	Died (day 1)
5	1 y, F	Liver transplantation	14	12	135	Yes	73	No	Yes	LD 1 mg/kg+MD 1 mg/kg/h	3	135	86	None	Died (day 1)
6	8 y, F	Crush syndrome	6	1	114	Yes	119	No	Yes	MD 1 mg/kg/h	1	114	120	None	Died (day 1)
7	19 y, F	Cystic fibrosis, CRF, pulmonary HT	4	1	154	Yes	104	Yes	No	MD 1 mg/kg/h	2	55	110	None	Died (day 28)
8	6 y, M	Hydrocephalus, CP, septic shock	8	12	100	Yes	72	No	No	LD 1 mg/kg+MD 1 mg/kg/h	3	88	103	None	Died (day 11)
9	22 m, M	Hirschsprung disease, sepsis	15	20	140	Yes	65	Yes	No	LD 1 mg/kg+MD 1 mg/kg/h	4	212	106	None	Died (day 1)
10	14 y, F	Amlodipine intoxication	8	11	100	Yes	101	No	No	LD 1 mg/kg+MD 1 mg/kg/h	3	15	119	None	Survived

PRISM III: Pediatric risk of mortality III, PELOD: Paediatric logistic organ dysfunction, VIS: Vasoactive-inotropic score, SBP: Systolic blood pressure, ECMO: Extracorporeal membrane oxygenation, CRRT: Continuous renal replacement therapy, BMT: Bone marrow transplantation, LD: Loading dose, MODS: Multiple organ dysfunction syndrome, MD: Maintenance dose, CRF: Chronic respiratory failure, HT: Hypertension, CP: Cerebral palsy

Table 2. Average clinical characteristics, therapies, and outcomes of patients receiving methylene blue (MB)

Variable	Minimum	Maximum	Mean ± SD
Age (years)	0.25	19	9.4±6.5
PRISM III score	4	14	9±3.2
PELOD score	1	20	10.6±5.9
Pre-MB VIS	35	216	116.4±90.5
Pre-MB SBP (mmHg)	56	119	81.3±19.0
Duration of MB use (days)	1	6	2.5±1.4
Post-MB VIS	30	216	109.9±75.8
Post-MB SBP (mmHg)	72	120	96.5±17.3

SD: Standard deviation, PRISM III: Pediatric risk of mortality III, PELOD: Paediatric logistic organ dysfunction, VIS: Vasoactive-inotropic score, SBP: Systolic blood pressure

received venoarterial ECMO. In all patients receiving CRRT or ECMO, SBP increased after MB administration, whereas reductions in VIS were inconsistent. Two ECMO patients demonstrated reductions in VIS and improvements in perfusion parameters, while others required stable vasopressor support. Despite short-term hemodynamic improvement, overall mortality remained high. Nine patients (90%) died during their PICU stay, whereas one patient—diagnosed with amlodipine intoxication—survived and was discharged in good clinical condition.

Figures 1 and 2 illustrate individual temporal changes in VIS and SBP following MB administration over the first 24 hours.

Discussion

This study describes one of the few pediatric series evaluating MB in catecholamine-resistant shock. MB administration was associated with a statistically significant short-term increase in SBP, whereas the reduction in the VIS was modest and was not statistically significant. Taken together, these findings indicate

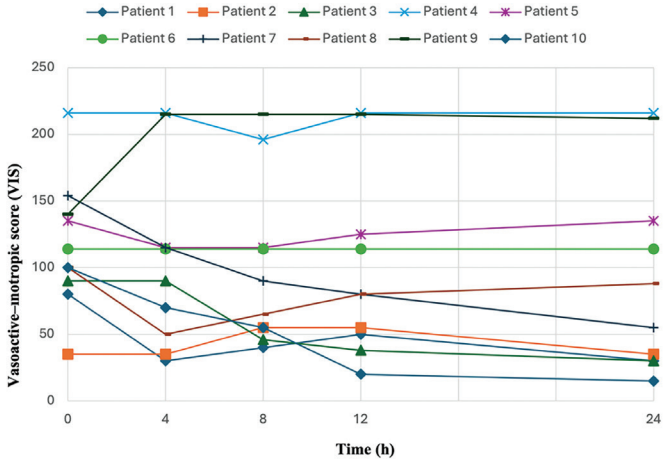

Figure 1. Individual vasoactive-inotropic score trajectories over 24 hours following methylene blue administration

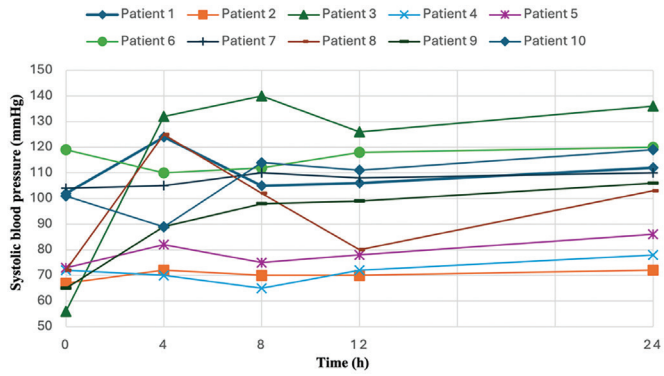

Figure 2. Individual systolic blood pressure trajectories over 24 hours following methylene blue administration

a transient hemodynamic improvement without evidence of a sustained reduction in vasoactive support, and they should be interpreted cautiously, given the small sample size and the lack of a control group.

The hemodynamic response observed after MB use is consistent with its mechanism of action through inhibition of nitric oxide synthase and sGC, which helps restore vascular tone and catecholamine responsiveness.[12,13] However, in our cohort, the limited improvement in VIS and the persistently high mortality rate (90%) likely reflect the advanced stage of shock and extensive multi-organ dysfunction at the time of MB initiation rather than treatment inefficacy.

Although a statistically significant increase in SBP was observed, this improvement did not translate into a survival benefit. This apparent discrepancy between short-term hemodynamic improvement and high mortality highlights the clinical context in which MB was used. In our study, MB was administered predominantly as a late rescue therapy in a highly selected population of critically ill children, many of whom required CRRT and/or ECMO support. Under these circumstances, MB may provide temporary physiological stabilization without altering the overall disease trajectory.

Previous pediatric studies evaluating MB in refractory shock have reported heterogeneous outcomes. Otero Luna et al.[27] reported improved blood pressure and reduced vasopressor requirements following MB administration, with lower reported mortality rates and limited use of advanced organ support. Similarly, Bitterman et al.[28] described favorable short-term hemodynamic responses in selected pediatric patients, most of whom did not require ECMO or CRRT at the time of MB initiation. In contrast, our cohort was characterized by a markedly greater severity of illness, a frequent need for ECMO and CRRT, and predominantly late administration of MB as rescue therapy. These differences likely explain the higher mortality observed in our study and highlight the unique

contribution of our series, which reflects real-world use of MB in the most critically ill pediatric patients.

The timing of MB appears to be crucial. Early administration, before irreversible endothelial injury occurs, may enhance efficacy.[7,9,12] In our cohort, MB was mostly used as a late rescue therapy, which may have limited its benefit. Nonetheless, no MB-related complications were observed, consistent with previous safety reports.[10,12,27] Particular caution should be exercised in patients with glucose-6-phosphate dehydrogenase deficiency or in those receiving serotonergic medications, as MB may precipitate hemolysis or serotonin syndrome.

MB administration in children with catecholamine-resistant shock was associated with a short-term improvement in SBP, without an observable survival benefit. Larger prospective studies are needed to clarify the optimal timing, dosing, and patient selection for MB therapy in pediatric shock.

Study Limitations

This study has several limitations. It was a retrospective, single-center analysis with a small sample size, thereby limiting the generalizability of the findings and precluding causal inference. The absence of a control group further restricts the interpretation of treatment effects. In addition, the timing and dosing of MB were not standardized, and concomitant therapies such as corticosteroids, vasopressin, CRRT, and ECMO may have influenced outcomes. Hemodynamic assessment was primarily based on changes in SBP and VIS; diastolic blood pressure and mean arterial pressure were not systematically recorded or compared; perfusion or biochemical markers were not available. Furthermore, blood pressure measurements were not standardized with respect to invasive versus noninvasive monitoring, and the cohort's small, heterogeneous composition with respect to inotrope selection and dosing precluded meaningful within-group comparisons of the MB effect. Finally, long-term follow-up data on survival or organ recovery were not available. Larger prospective multicenter studies are needed to confirm the safety and efficacy of MB in pediatric catecholamine-resistant shock.

Conclusion

Methylene blue was associated with a short-term increase in systolic blood pressure in children with catecholamine-resistant shock, but its effect on vasoactive support was inconsistent and mortality remained high. Although no treatment-related adverse events were observed, larger prospective studies are needed to determine its optimal timing, dosing, safety, and clinical benefit.

Ethics

Ethics Committee Approval: The study protocol was approved by the Ankara University Human Research Ethics Committee (approval no: I04-406-24, date: 11.06.2024).

Informed Consent: Written informed consent for treatment and data use was obtained from the families of all participants.

Acknowledgments

In this research report, all individuals who contributed to this article are listed as authors. We would like to thank everyone who contributed to this study as mentioned above.

Footnotes

Authorship Contributions

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

Conflict of Interest: No conflict of interest was declared by the authors. One of the authors of this article (T.K.) is a member of the Editorial Board of this journal. He had no involvement in the peer-review process or editorial decision regarding this manuscript. The peer-review process and editorial decision were handled independently by another editor.

Financial Disclosure: The authors declared that this study received no financial support.

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Research Article / Özgün Araştırma

DOI: 10.4274/cayd.galenos.2026.26539
J Pediatr Emerg Intensive Care Med 2026;13(2):101-8

Assessment of Acute Poisoning Cases Admitted to the Pediatric Intensive Care Unit: A Tertiary Hospital Experience

Çocuk Yoğun Bakım Ünitesine Yatırılan Akut Entoksikasyon Olgularının Değerlendirilmesi: Bir Üçüncü Basamak Hastane Deneyimi

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Abstract

Introduction: Pediatric intoxications are frequently encountered in emergency departments and pediatric intensive care units and may lead to significant morbidity and mortality. This study aims to evaluate the etiological factors, clinical characteristics, treatment approaches, and outcomes of acute intoxication cases admitted to the pediatric intensive care unit of a tertiary care center and to describe the regional intoxication profile.

Methods: This retrospective study included 391 children hospitalized with acute intoxication in the Pediatric Intensive Care Unit of Bolu Abant İzzet Baysal University Faculty of Medicine between 2012 and 2018. Demographic variables, type and intent of intoxication, route of exposure, time to presentation, clinical findings, treatments, length of stay, and outcomes were collected from hospital information systems and medical records. Statistical analyses were performed using IBM SPSS v22 with a significance level of $p<0.05$.

Results: The mean age was 7.9±6 years; 52.4% were younger than five years, 39.6% were adolescents, and 62.4% were female. Most intoxications occurred at home (89%) and were accidental (66.4%), while intentional ingestions were significantly more common among adolescents and females ($p<0.001$). A seasonal increase was noted in summer. Oral ingestion was the predominant exposure route, and medications accounted for 70.8% of toxic agents, especially analgesics and central nervous system drugs. Rodenticide exposure was more frequent in younger children. Many patients were asymptomatic at presentation; hydration (60.6%), gastric lavage, and activated charcoal (58.8%) were the most common treatments. Antidotes, mechanical ventilation, and hyperbaric oxygen therapy were required in selected cases. The mean pediatric intensive care unit stay was 1.6±1.1 days, and the mortality rate was 0.5%.

Öz

Giriş: Çocukluk çağı entoksikasyonları, acil servis ve çocuk yoğun bakım ünitelerinde sık karşılaşılan, morbidite ve mortalite açısından önemli sonuçlar doğurabilen klinik tablolardır. Bu çalışma, üçüncü basamak bir merkezde çocuk yoğun bakım ünitesine yatırılan akut entoksikasyon olgularının etkenlerini, klinik özelliklerini, uygulanan tedavi yaklaşımlarını ve sonuçlarını değerlendirerek bölgesel entoksikasyon profilini ortaya koymayı amaçlamaktadır.

Yöntemler: Bu geriye dönük çalışma, 2012-2018 yılları arasında Bolu Abant İzzet Baysal Üniversitesi Tıp Fakültesi, Çocuk Yoğun Bakım Ünitesi'ne akut entoksikasyon tanısıyla yatırılan 391 olguyu içermektedir. Demografik özellikler, zehirlenme nedeni ve şekli, maruziyet yolu, başvuru zamanı, klinik ve fizik muayene bulguları, tedavi yaklaşımları, yatış süreleri ve sonuçlar hastane bilgi yönetim sistemi ve arşiv dosyalarından elde edilmiştir. Veriler IBM SPSS v22 programı ile analiz edilmiş, uygun istatistiksel testler kullanılmış ve $p<0,05$ anlamlı kabul edilmiştir.

Bulgular: Olguların yaş ortalaması 7,9±6 yıl olup, %52,4'ü beş yaşından küçük, %39,6'sı ergen yaş grubundaydı; %62,4'ü kızdı. Zehirlenmelerin çoğu ev ortamında (%89) ve kazara (%66,4) gelişirken, özkıyım amaçlı entoksikasyonlar belirgin olarak adölesanlarda ve kızlarda daha sık izlendi ($p<0,001$). Mevsimsel değerlendirmede yaz aylarında başvuruların arttığı saptandı. En sık maruziyet yolu oral alım olup, toksik etkenlerin %70,8'ini ilaçlar oluşturdu; analjezikler ve santral sinir sistemi ilaçları başlıca sorumlu gruplardı. Rodentisit maruziyeti özellikle küçük yaş grubunda dikkat çekiciydi. Olguların önemli bir kısmı başvuruda asemptomatik olup, başvuru sonrası en sık uygulanan tedaviler hidrasyon (%60,6), gastrik lavaj ve aktif kömürdü (%58,8); seçilmiş olgularda antidot, mekanik ventilasyon ve hiperbarik oksijen tedavisi uygulandı. Ortalama yoğun bakım yatış süresi 1,6±1,1 gün, mortalite oranı ise %0,5 olarak bulundu.

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Received/Geliş Tarihi: 19.11.2025 **Accepted/Kabul Tarihi:** 10.03.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: İldeş EN, Bekdaş M, Dilek M, Kabakuş N. Assessment of acute poisoning cases admitted to the pediatric intensive care unit: a tertiary care hospital experience. J Pediatr Emerg Intensive Care Med. 2026;13(2):101-8

Abstract

Conclusion: Accidental intoxications predominated in young children, whereas intentional ingestions were more common among adolescents. Medications were the leading toxic agents. Early recognition, appropriate decontamination, and intensive care support contributed to the low mortality. Strengthening family education, ensuring safe storage of toxic substances, regulating rodenticide use, and implementing preventive mental health programs for adolescents may help reduce pediatric intoxications.

Keywords: Child, acute intoxication, poisoning, pediatric intensive care, drug poisoning, intentional drug ingestion

Öz

Sonuç: Bulgular, çocukluk çağında kazara, ergenlerde ise özkıyım amaçlı entoksikasyonların öne çıktığını ve ilaçların temel toksik ajanı oluşturduğunu göstermektedir. Erken başvuru, uygun dekontaminasyon ve yoğun bakım desteği ile mortalitenin düşük tutulabileceği görülmektedir. Bölgesel veriler, aile eğitimi, güvenli ilaç ve toksik madde saklanması, rodentisit kullanımının kontrolü ve ergen ruh sağlığına yönelik koruyucu programların güçlendirilmesi gereğini vurgulamaktadır.

Anahtar Kelimeler: Çocuk, akut entoksikasyon, zehirlenme, çocuk yoğun bakım, ilaç zehirlenmesi, özkıyım amaçlı ilaç alımı

Introduction

Acute poisonings account for a significant proportion of pediatric emergency department visits and intensive care admissions. Particularly during early childhood, developmental curiosity, exploratory behavior, and easy access to household toxic substances place this age group at higher risk. According to the 2023 report of the National Poison Data System (NPDS) in the United States, 39.6% of reported cases involved children under five years of age.[1] In Türkiye, data from the National Poison Control Center for 2020 show that 25.1% of reported cases also involved this age group.[2] Data from the Turkish Statistical Institute also reveal that external causes and poisonings are the most frequently identified causes of death among children aged 1-17.[3] These findings demonstrate that poisonings in childhood are not only common but also represent a clinical condition requiring attention due to their potential consequences.

The substances causing poisoning and the mode of exposure may vary according to age, sex, educational level, and socioeconomic characteristics. These variables can directly influence the clinical manifestations, morbidity, and mortality rates of poisoning cases. Therefore, every country requires centers equipped to manage poisoning cases.[4] Additionally, the mode of ingestion of toxic substances varies with age; accidental ingestion is more common in childhood, while intentional exposure is reported to be more prevalent in the adolescent age group.[5]

The aim of this study was to evaluate the etiological distribution, clinical characteristics, and outcomes of pediatric acute poisoning cases requiring intensive care, thereby establishing a regional profile and contributing to preventive strategies.

Materials and Methods

This retrospective study was conducted from 2012 to 2018 in the six-bed tertiary pediatric intensive care unit of the Bolu Abant İzzet Baysal University Faculty of Medicine. The unit did not have a pediatric intensive care specialist, and patient management was carried out by a pediatrician. The attending physician had experience in pediatric intensive care, and the patient's diagnosis, treatment, and follow-up were conducted in accordance with the current guidelines.

The study included patients aged 1 month to 18 years who were admitted to the pediatric intensive care unit with a diagnosis of acute poisoning during the specified period. Patients with incomplete records, those under 1 month of age, and those over 18 years of age were excluded from the study.

Patient data were obtained from the hospital information management system and from archived records. Demographic characteristics (age, sex), presentation locations (city center, district, referral from neighboring provinces), the causative agent of poisoning, the mode of poisoning (accident/suicide), time of presentation (month, season), time of poisoning, environment of exposure to the toxic substance, time elapsed since exposure (<1 hour, 1-6 hours, >6 hours), clinical findings, laboratory results, treatments administered, and clinical outcomes were recorded. Age groups were defined according to the developmental stage classification commonly used in pediatric clinics: 1 month-5 years as the "early childhood period", 6-11 years as the "school-age period", and 12-18 years as the "adolescent period".

The times of poisoning onset were recorded and categorized into the intervals 06:00-12:00 and 18:00-06:00 to establish clinically meaningful periods. The relationship between the onset times, age groups, and intoxication type (accidental or suicidal) was statistically analyzed.

The treatments administered included supportive care (hydration), gastric lavage, activated charcoal administration, antidote therapy, mechanical ventilation, and inotropic support. Initial evaluation and treatment of the patients were performed in the emergency department, and those requiring intensive care were admitted to the pediatric intensive care unit for monitoring. Emergency department management

and intensive care unit management were analyzed together. Clinical outcomes were recorded as length of stay in the intensive care unit, discharge, transfer, and mortality.

Ethics Approval

Approval for the study was obtained from the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee (approval no: 2018/204, date: 13.12.2018).

Statistical Analysis

IBM SPSS Statistics v22.0 was used for data analysis. Continuous variables were assessed for normality using the Kolmogorov-Smirnov test. Variables with a normal distribution were presented as mean ± standard deviation, while those without a normal distribution were presented as median (minimum-maximum). Categorical variables were expressed as frequencies (n) and percentages (%). For comparisons between groups, the chi-square test or Fisher's exact test was used; for continuous data, the independent-samples t-test or the Mann-Whitney U test was used. A p-value of <0.05 was considered statistically significant.

Results

A total of 391 patients admitted to the pediatric intensive care unit during the study period were included in the analysis. Mean age of the patients was 7.9±6.0 years, with ages ranging from 2 months to 17 years. Of the patients, 147 (37.6%) were male and 244 (62.4%) were female. When the distribution by age group was examined, 1.8% of cases were in the 2-12-month age group, 50.6% in the 1-5-year age group, 7.9% in the 6-11-year age group, and 39.6% in the 12-18-year age group.

When the settings in which poisonings occurred were evaluated, 89% of cases occurred in the home. Less frequently, cases were reported at school (0.7%), in a neighbor's home (2%), on the street (1.7%), and in other settings (6.3%).

When the distribution of cases by season was examined, 24.3% occurred in the spring, 27.1% in the summer, 26.6% in the fall, and 22% in the winter. In terms of geographic distribution, 55.5% of patients were referred from the central district of Bolu, 25.6% from surrounding districts, and 18.9% from neighboring provinces.

When the causes of poisoning were evaluated, it was determined that 66.4% of cases were accidental, while 33.5% were intentional (suicide). When the age group distribution was examined, accidental poisonings were significantly higher in children, whereas suicide-related poisonings were significantly more common among adolescents [6.8% (n=9) versus 88.4% (n=227) and 11.6% (n=30) versus 93.2% (n=125); p<0.001].

When the relationship between gender and type of poisoning was evaluated, accidental exposures were more common among males, while suicide-related poisonings were significantly higher among females [accidental: males 50.4% (n=131) vs. females 12.2% (n=16); suicide-related: females 87.8% (n=115) vs. males 49.6% (n=125); p<0.001].

When methods for detecting poisoning were examined, it was determined that the diagnosis was made in 20.2% of cases at the onset of symptoms, in 18.4% of cases upon noticing medication left out in the open, in 24.8% of cases while the medication was being ingested, and in 23.5% of cases when the patient reported the ingestion of the toxin. In the remaining 13% of cases, a diagnosis of intoxication was made based on clinical and laboratory findings in patients presenting for other reasons.

Evaluation of the clinical findings at presentation (Table 1) showed that 66.8% of patients were asymptomatic. The most common complaints among symptomatic patients were nausea and vomiting, accounting for 14.3%.

The distribution of intoxicating agents is shown in a donut chart in Figure 1. Evaluation of the causes of poisoning showed that drug-related exposures constituted the largest group (70.8%).

When drug groups were examined, central nervous system-acting drugs accounted for 41.5% (n=115), analgesics for 40.4% (n=112), antihypertensives for 8.3% (n=23), gastrointestinal system medications for 2.1% (n=6), antibiotics for 2.1% (n=6), antihistamines for 2.1% (n=6), iron preparations for 0.7% (n=2), and other agents for 2.5% (n=7). When individual drugs were evaluated, paracetamol was found to be the most common causative agent (21.2%) (Figure 2).

When drug-induced poisonings were evaluated, 75% of cases involved a single-drug, while 25% involved ingestion of multiple drugs. When analyzed by gender, single-drug poisonings were more common in male patients, whereas multiple-drug poisonings were significantly more frequent in female patients [10.1% (n=7) vs. 41.8% (n=87) and 58.1%

Table 1. Distribution of clinical symptoms at presentation

Clinical symptom	Number of cases (n)	Percentage (%)
Asymptomatic	261	66.8
Nausea-vomiting	56	14.3
Abdominal pain	6	1.5
Drowsiness	30	7.7
Loss of consciousness	23	5.9
Agitation	14	3.6
Convulsion	1	0.3
Total	391	100.0

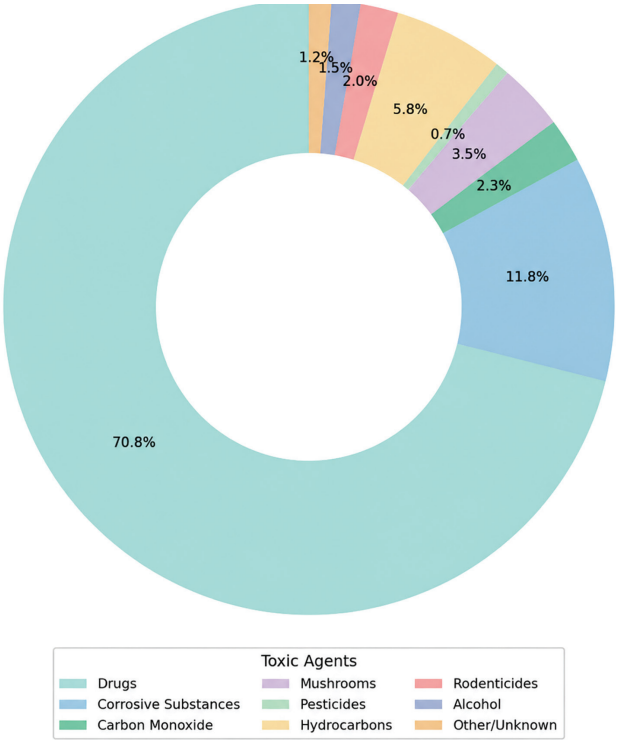

Figure 1. Distribution of toxic agents

(n=121) vs. 89.8% (n=62), p<0.001]. When evaluated by age group, single-drug ingestion-related intoxications were more prevalent in childhood, whereas multiple-drug ingestion was significantly higher in adolescents [60.8% (n=124) vs. 25% (n=17), and 39.2% (n=80) vs. 75% (n=51), p<0.001].

The timing of intoxications varied by age group. In pediatric patients, exposure to toxins occurred more frequently between 06:00-12:00, whereas in adolescents it predominated during the 18:00-06:00 time window [54.7% (n=81) vs. 74.4% (n=61); 25.6% (n=21) vs. 45.3% (n=67), p=0.011]. When the relationship between the type of poisoning and the time of occurrence was examined, accidental poisonings occurred more frequently between 6:00-12:00 PM, whereas suicide-related poisonings were significantly more common during the 6:00 PM-6:00 AM window [60.3% (n=88) vs. 83.1% (n=69) and 16.9% (n=14) vs. 39.7% (n=58), p=0.001].

Physical examination findings at presentation are summarized in Table 2. Upon evaluation, no pathological physical examination findings were observed in 76.2% of the patients at the time of presentation.

When emergency department presentation times were analyzed by age group, the majority of pediatric patients presented within the first hour after poisoning, whereas adolescents presented more frequently after the first 6 hours [42.3% (n=11) vs. 68.8% (n=163) and 31.2% (n=74) vs. 57.7% (n=15), p<0.001].

When time to presentation was evaluated by type of poisoning, most patients with accidental poisoning reached a healthcare facility within the first hour, whereas presentations for poisonings with suicidal intent were more common in the 1-6-hour window [57.7% (n=56) versus 73.6% (n=176) and 26.3% (n=63) vs. 42.3% (n=41), p=0.009] (Table 3).

It was determined that the mean age of the patients diagnosed with drug-induced intoxication was statistically significantly higher compared to patients exposed to rodenticides (rat poison) (8.9±6.2 years vs. 3.8±4.1 years, p=0.003). No significant association was observed between age and other toxic agents (p>0.05).

The distribution of treatment approaches is shown in Figure 3. When treatment methods were examined, the most frequently used interventions were hydration (60.6%) and gastric lavage combined with activated charcoal (58.8%).

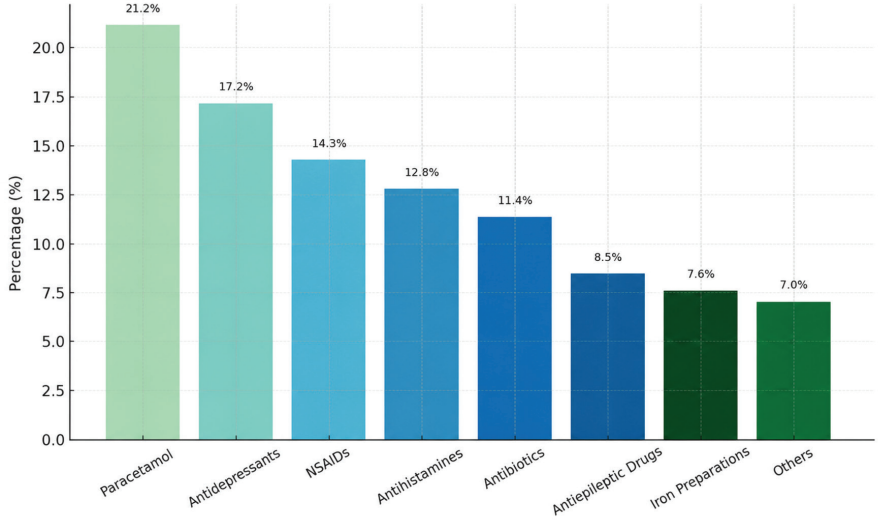

Figure 2. Distribution of drug classes causing poisoning

Table 2. Distribution of physical examination findings at presentation

Physical examination finding	Number of cases (n)	Percentage (%)
No pathological findings	298	76.2
Dyspnea	9	2.3
Tachypnea	8	2.0
Tachycardia	60	15.3
Hypertension	8	2.0
Skin hyperemia	3	0.8
Oral mucosal burn	2	0.5
Miosis	2	0.5
Mydriasis	1	0.3
Total	391	100.0

The average hospital stay was 1.6±1.1 days, ranging from 1 to 15 days. When the intensive care unit length of stay was evaluated by sex, it was found to be 1.6±1.5 days for male patients and 1.6±0.8 days for female patients, and no statistically significant difference was detected between the groups (p=0.12).

The vast majority of patients in the study group were discharged (97.7%; n=382). Seven patients (1.8%) were transferred to another center to receive hyperbaric oxygen therapy, and two patients (0.5%) died. One patient died from carbon monoxide (CO) poisoning, while the other died from complications following administration of high-dose intravenous diazepam after an epileptic seizure in a neighboring province.

Discussion

Acute poisonings in children rank among the preventable causes of morbidity both globally and in our country. When examining health issues related to traumatic and external causes in Türkiye, it is reported that poisonings rank fourth after traffic accidents, falls, and burns.[6] The 2023 NPDS report by the American Association of Poison Control Centers states that 39.6% of reported intoxication cases involved children under five years of age.[1] Most exposures in this age group occur in the home environment and are accidental; the most common agents involved are cleaning products, analgesics, and cosmetic and personal care products. Similarly, our study found that 52.4% of poisoning cases involved children under five years of age, and accidental ingestion was predominant in this group. Additionally, analgesics were found to be the most common toxic agents. These results are consistent with current NPDS data and demonstrate that accidental intoxications in childhood remain a significant concern.

Table 3. Time to emergency service presentation after intoxication according to age group and type of intoxication

Characteristics	Time to emergency service presentation after intoxicattion			p-value
	<1 h	1-6 sh	>6 h	
Child adolescent	(68.8%)	46 (46.9%)	11 (42.3%)	<0.001
	74 (31.2%)	52 (53.1%)	15 (57.7%)	
Accident suicide	176 (73.6%)	56 (57.7%)	13 (42.3%)	0.009
	63 (26.3%)	41 (42.3%)	12 (48%)	

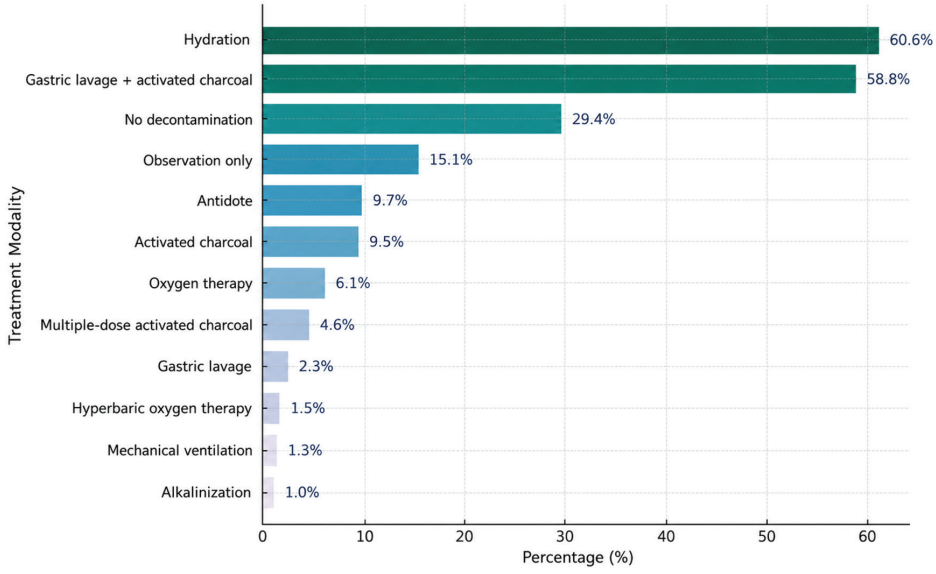

Figure 3. Major treatment modalities in the intensive care unit and emergency department

When the months of presentation were examined, cases were most frequent in August (12%) and least frequent in January (4.9%), reflecting an increase during the summer season. This finding, consistent with the spring-summer increase reported by Zhang et al.[7] differs from a more recent study conducted in Iran that reported an autumn peak.[8] These findings suggest that the seasonal distribution of poisonings does not follow a fixed pattern; rather, it may vary depending on geographic location, cultural characteristics, and environmental factors. The seasonal trends reported in the literature are associated with numerous factors, including regional climatic conditions, lifestyle habits, access to household chemicals, school vacations, and increased time spent outdoors by children.

It has been reported that the increase observed during the summer months may be linked to children spending more time outdoors, having easier access to chemicals used for agricultural and cleaning purposes, and an increased likelihood of exposure to toxic substances in open areas.[7] Additionally, changes in family routines and reduced supervision during the summer may increase the risk of exposure.

When cases are evaluated by age group, 52.4% are in the 0-5 age group and 39.6% are in the adolescent age group. Poisonings in the younger age group were largely accidental, whereas those during adolescence were frequently intentional. This finding is consistent with similar studies conducted in our country.[9,10] The NPDS 2021 report also emphasizes that rates of intentional exposure have increased, particularly among female adolescents.[11] Various psychosocial factors may underlie the higher rates of intentional exposure among female adolescents. Depression, anxiety disorders, difficulties with emotional regulation, and a predisposition to self-harm are among the risk factors more frequently reported in this group. Additionally, the literature indicates that female adolescents tend to prefer less lethal methods compared to males and often engage in interventions such as medication ingestion.[11,12]

When presentation times were evaluated, a significant proportion of children under five years of age were brought to healthcare facilities within the first hour after poisoning, whereas adolescents mostly presented within the 1-6 hour interval. This difference may be explained by earlier recognition by family members of exposure in younger children. In the study conducted by Guzel et al.,[13] the mean time to presentation to the emergency department after intoxication in children was reported as 105 minutes. Similarly, NPDS 2023 data indicate that accidental exposures in the United States are generally recognized early, whereas intentional exposures (suicide attempts) are reported later, and this delay is associated with more severe clinical outcomes.[1]

Mortality rates associated with pediatric poisonings are reported to be quite low in the literature (≤0.05%).[1] In our country, this rate has been reported to range between 0% and 5.4%.[9,14,15] In our study, the mortality rate was found to be 0.5%. This low rate may be associated with early presentation, application of appropriate decontamination methods, and close monitoring in intensive care.

In the literature, it has been reported that 5% to 30% of beds in adult intensive care units are allocated to the monitoring of poisoning cases.[16] Although this rate is more limited in pediatric intensive care units, in the series reported by Özkale and Özkale[17], intoxication cases constituted 15.3% of all admissions. In our study, the proportion of poisoning cases among patients admitted to the pediatric intensive care unit was 19.1%. The higher rate compared to some pediatric series in the literature may be explained by the fact that the only pediatric intensive care unit in our province is located in our hospital, and that referrals from within the province and surrounding regions are largely directed to our center.

The route of exposure to the toxic agent is important for the clinical course and risk assessment. In our study, exposure occurred via the oral route in 83.1% of cases. This finding is consistent with the current literature, which indicates that oral intake is the most common form of exposure in childhood poisonings. In a multicenter study conducted in China, 96.8% of pediatric acute poisoning cases occurred through oral intake, and most of these cases were accidental.[18] The predominance of oral exposure among younger age groups is thought to be related to the tendency of children under five to explore objects through their mouths and to their easy access to toxic substances commonly found in the home environment.

In a multicenter study, it was reported that poisoning via inhalation ranked second after oral intake, with CO remaining the primary agent in this group.[18] Recent pediatric series show that inhalation poisonings, especially those caused by CO, can lead to significant morbidity. It is also emphasized that the clinical course may be more severe in cases of CO poisoning presenting with neurological symptoms.[19]

Similarly, inhalation was identified in our study as the second most common route of exposure to toxic substances. Despite the widespread use of natural gas, CO intoxications, still ranking second, suggest that coal use continues in the community. CO exposures are mostly caused by stoves, chimneys, and heating systems with inadequate ventilation and tend to increase, especially during the winter months.[20]

When the causes of acute intoxications were examined, 70.8% of cases were found to be related to drug exposure. Paracetamol, antidepressants, and non-steroidal anti-inflammatory drugs were among the most common agents.

In the study reported by Sinanoglu and Berk[21], drugs were also identified as the primary cause of pediatric poisonings, with non-steroidal anti-inflammatory drugs being the most

common agents at a rate of 21%. Similarly, Guzel et al.[13] reported that 66.4% of poisoning cases were drug-related, and 23.4% of these were from the analgesic-antipyretic group. Taken together, these findings suggest that drugs continue to be the predominant factor in childhood poisonings because they are easily accessible and frequently used in the home.

Rodenticide exposures, which are expected to decrease with increasing urbanization, remain a notable cause of poisoning among children. In our study, the rate of rodenticide intoxication was 5.8%, which is consistent with current national and international studies. In a multicenter pediatric study, rodenticide exposure was reported at a rate of 6.7%.[18] Studies conducted in Türkiye also indicate that the proportion of rodenticides in childhood poisonings is approximately 5-6%.[13,22] The toxic agents that cause poisoning may vary by age group. In our study, the mean age of patients with rodenticide-related poisoning was significantly lower than that of patients with drug-related poisoning (p=0.003). This suggests that children, especially those aged 1-5 years, are at higher risk due to exposure to rodenticides left on the ground or otherwise readily accessible in the home.

Evaluation of the treatment methods applied in our study showed that supportive treatments and early decontamination interventions were prominent. Hydration therapy was administered in 60.6% of cases, indicating that maintaining hemodynamic stability is the primary approach in pediatric acute poisoning.

Additionally, the combined use of gastric lavage and activated charcoal in 58.8% of cases suggests that gastrointestinal decontamination plays an important role in clinical management, particularly in patients who present early. Current guidelines limit the use of gastric lavage to cases involving toxins with high lethality potential and to cases presenting within the first hour. Activated charcoal is accepted as an effective and commonly preferred decontamination method in early-presenting cases.[23]

The administration of antidotes in 9.7% of cases and the preference for observation alone in 15.1% of cases indicate that individualized evaluation was performed in treatment management. The relatively low rates of advanced treatments, such as hyperbaric oxygen (1.5%) and mechanical ventilation (1.3%), demonstrate that critical cases were few, and that advanced life support approaches could be effectively applied when necessary.[19]

Study Limitations

First, due to its single-center and retrospective design, the study may have limitations related to missing records and data accuracy. Since the study included only cases admitted to the pediatric intensive care unit, mild cases and those managed at the emergency department or ward level were excluded from the evaluation. In addition, practices in the emergency department and in intensive care were not analyzed separately. Furthermore, because long-term neuropsychiatric follow-up and post-discharge data were not available, the long-term outcomes of intentional exposures, particularly among adolescents, could not be assessed.

Conclusion

Such regional studies provide important data that can shape not only clinical management but also preventive medicine for pediatric emergency and intensive care services. Prevention of childhood intoxications can be achieved through developing local policies targeting toxic agents that are particularly prevalent in rural areas, enhancing environmental safety measures, and implementing community-based education programs.

Ethics

Ethics Committee Approval: Approval for the study was obtained from the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee (approval no: 2018/204, date: 13.12.2018).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Concept: E.N.İ., Design: E.N.İ., M.B., N.K., Data Collection or Processing: M.B., Analysis or Interpretation: M.D., Literature Search: E.N.İ., N.K., Writing: E.N.İ., M.B., M.D.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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Research Article / Özgün Araştırma

DOI: 10.4274/cayd.galenos.2026.77598
J Pediatr Emerg Intensive Care Med 2026;13(2):109-16

A Qualitative Research on the Experiences and Feelings of Pediatric Emergency Service Nurses with Refugee Children and Parents

Çocuk Acil Servisi Hemşirelerinin Mülteci Çocuklar ve Aileleri ile Duygu ve Deneyimleri Üzerine Nitel Bir Araştırma

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Abstract

Introduction: This study examined nurses' experiences and feelings when providing care to refugee children and parents in the pediatric emergency service.

Methods: In this phenomenological research design, data were collected using a semi-structured interview form. The study was conducted among 12 nurses working in the pediatric emergency department of a university hospital in Türkiye between September and October 2022.

Results: The average age of the nurses who participated in the study was 34.5 years, and the average duration of employment in the pediatric emergency services was 4 years. Based on content analysis, the themes of the study were identified as follows: (1) problems experienced (increased workload, communication problems, parents' lack of health knowledge), (2) neglected child-related sadness (low socio-economic status, inadequate parental child care), (3) professional responsibility (professional awareness, professional ethics).

Conclusion: Nurses stated that, with the addition of refugees to the country's population, there are problems in the healthcare system and an increased workload. Problems faced by refugees regarding socio-economic status, language and communication, and health literacy are also emphasized. It has been determined that they feel sympathy for these problems, but they endeavor to continue providing care without discrimination due to their professional ethical responsibilities.

Keywords: Pediatric emergency service, nurse, refugee child, refugee parent, qualitative research, experiences, feeling

Öz

Giriş: Bu çalışma, çocuk acil servisinde mülteci çocuklara ve ailelerine bakım veren hemşirelerin duyguları ve deneyimlerini incelemek amacıyla yapıldı.

Yöntemler: Fenomenolojik tasarıma sahip bu araştırmanın verileri yarı yapılandırılmış görüşme formuyla toplanmıştır. Araştırma, Eylül-Ekim 2022 tarihleri arasında Türkiye'deki bir üniversite hastanesinin çocuk acil servisinde çalışan 12 hemşire ile gerçekleştirildi.

Bulgular: Araştırmaya katılan hemşirelerin yaş ortalaması 34,5 olup çocuk acil servisinde ortalama çalışma süresi 4 yıldır. İçerik analizine dayalı olarak çalışmanın temaları şu şekilde belirlenmiştir: (1) yaşanan sorunlar (iş yükünün artması, iletişim sorunu, ebeveynlerin sağlık bilgisi eksikliği), (2) ihmal edilen çocuk kaynaklı üzüntü (sosyo-ekonomik durumun yetersizliği, ebeveynlerin çocuk bakımının yetersizliği), (3) mesleki sorumluluk (mesleki farkındalık, mesleki etik).

Sonuç: Hemşireler, ülke nüfusuna göçmenlerin de eklenmesiyle sağlık sisteminde bazı sorunların yaşandığını ve iş yükünün arttığını belirtmişlerdir. Göçmenlerin sosyo-ekonomik durum, dil-iletişim, sağlık okuryazarlığı gibi konulardaki sorunları da vurgulanmaktadır. Bu sorunlara üzüldükleri ancak mesleki etik sorumlulukları nedeniyle ayrımcılığa uğratmadan bakım vermeye devam etmeye çalıştıkları belirlendi.

Anahtar Kelimeler: Çocuk acil servis, hemşire, mülteci çocuk, mülteci ebeveyn, nitel araştırma, deneyimler, duygu

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Received/Geliş Tarihi: 06.10.2025 **Accepted/Kabul Tarihi:** 02.04.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Demir Acar M, Yılmaz G, Yüzer Alsaç S, Coşkun Şimşek D. A qualitative research on the experiences and feelings of pediatric emergency service nurses with refugee children and parents. J Pediatr Emerg Intensive Care Med. 2026;13(2):109-16

Introduction

The United Nations Refugee Agency determined that 79.5 million individuals worldwide were forcibly displaced by the end of 2019.[1] Türkiye hosted the largest number of displaced individuals, nearly 3.9 million, of whom 92% were Syrian refugees. The majority of these individuals are children aged 0-18 (47.4%) and women (46.2%).[2]

The movement of refugee populations has affected the demographic, cultural, and socio-economic structures of all recipient countries, including Türkiye.[3] This vulnerable population, which is increasing in number, particularly along the southern border of Türkiye, poses challenges to the health system and contributes to socio-economic problems.[4] Apart from these problems, refugees face major challenges, and they may shift health service priorities in their host countries.[5] A study was conducted on access to primary health services for refugees: a qualitative study of service user experiences in the United Kingdom by Kang et al.[6] Basic themes included inadequate interpretation of services and language barriers; lack of awareness of the functions and structure of the National Health Service; perception of discrimination relating to religion, race, and refugee status; and problems meeting the costs of dental health, prescription fees, and transport to appointments. Published research articles on child refugees living outside Africa focus on infectious diseases, physical and mental health, food insecurity, neurodevelopmental disorders, psychosocial adjustment, and health promotion strategies.[7] In addition, in emergency services, health literacy, cultural, and language difficulties make it potentially challenging to provide quality care for refugee parents, their children, and health professionals.[8]

Healthcare teams often work in stressful and fast-paced environments while caring for patients with complex and demanding needs. Health professionals often help their patients and families cope with difficult diagnoses, traumatic injuries, and death.[9] Emergency nurses are trained to evaluate and triage patients and to collaboratively treat patients in the early stages of acute illness and trauma. Emergency nurses work in a stressful environment where they routinely witness personal tragedies. Pediatric nurses may experience higher levels of stress than other nurses; often, in addition to caring for the crying child, they also attend to and comfort the child's parents. Pediatric emergency nurses face greater professional challenges.[10-12] Secondary traumatic stress (STS) affects many health professionals.[13] Given that more than a quarter of service providers have moderate to severe STS, anxiety, and depression, future intervention research should address the well-being of both crisis-affected individuals and crisis responders. For this reason, research should build on qualitative findings to better understand both the specific mechanisms of employee mental health and their relationship to perceived organizational or institutional support.[14]

Culturally competent clinical care is a concept often used to describe how health care teams can effectively and appropriately treat culturally and ethnically diverse patients. There is an increased need for health care professionals to be more attuned to the behavioral health needs of racial and ethnic minorities and to the role of the social environment.[15] Given the environmental characteristics of emergency services, a strategy should be developed to support health professionals in communicating effectively with refugee patients and their parents about culturally appropriate care.[16,17]

This study sought to answer the following question: what are the beliefs and feelings of emergency nurses working in pediatric emergency services regarding refugee families? What is the essence of nurses' experiences working in pediatric emergency services with refugee families?

Materials and Methods

Characteristics and Location of the Research

The study examined nurses (participants: P) caring for refugee patients at one university hospital in an urban center of the Middle Black Sea Region of Türkiye between September and October 2022.

Study Design

This research focused on a phenomenological approach, one of the qualitative research methods.[18] Phenomenological research is based on understanding the essence of human experiences and on exploring the meaning people attribute to those experiences.[19] The study was conducted and reported in accordance with the consolidated criteria for reporting qualitative studies.

A purposive sampling method was used in this research. Nurses who cared for refugee parents in pediatric emergency services constituted the study sample. In qualitative studies, the data can be obtained from field study observations, written documents, in-depth interviews, and audio recordings.[19]

Demographics of the Qualitative Sample

The number of healthcare professionals working in the pediatric emergency unit is 22 (8 doctors and 14 nurses). Nurses who worked in the pediatric emergency unit for at least one year were included. One nurse had been working for less than one year, and one of them had been on leave. The study included twelve nurses: eight female and four male. Although no rule is specified for sample size in the literature for qualitative studies, failure to obtain additional data and repetition of data are important indicators for terminating data

collection. In-depth interviews aim to reach data saturation.[20] Data saturation was reached when nurses began to use the same or similar expressions and was achieved with twelve nurses. Saturation was reached after the 10th interview, and the last 2 interviews were conducted for completeness.

Inclusion criteria of nurses in the study:

1) Agreeing to participate in the study,

2) Nurses who worked in the pediatric emergency unit for at least one year were included.

Data Collection

The data were collected using a semi-structured interview form. A pilot test was conducted with a nurse to ensure internal validity. The suitability of the questions was determined by consulting two experts with doctoral degrees whose qualitative work on pediatric nursing is indexed in the science citation index.

The questions were finalized in line with their suggestions. To collect data, the researchers prepared four basic, open-ended questions:

1) "Can you tell me about your experience working with pediatric refugee patients?"

2) "Have you ever had difficulties while caring for refugee patients? Can you explain?"

3) "How did working with refugee patients affect your thoughts about your profession?"

4) "What emotions do you experience while caring for refugee patients? Can you explain?"

In-depth interviews were conducted in the nurses' office of the pediatric emergency unit in a quiet environment. The first and second authors (M.D.A. and G.Y.) conducted the interviews. The interviews lasted an average of 20 minutes. Before the in-depth interviews, participants provided permission for voice recordings.

Statistical Analysis

The data were analyzed using the content analysis method. This research method focuses on obtaining reproducible and valid results regarding the content of the data.[21,22]

After the interviews were completed, the researchers transcribed all the audio recordings into text on the computer. Data analysis was carried out in seven stages according to Colaizzi[21]: 1) The written texts were read meticulously and repeatedly by the researchers independently of each other. 2) Expressions suitable for the study were identified. 3) Expressions were grouped. 4) Similar or identical expressions were grouped together, and distinct, noteworthy expressions were identified. 5) The main themes of the study (problems experienced, sadness about the neglected child, professional responsibility) were identified and described in detail. 6) The core structure of the participants' experiences was described. 7) The results of the analysis were presented to the participants. Thus, the accuracy and security of the findings were ensured.

Content analyses were conducted independently by researchers to ensure data consistency. The opinions of two experts not involved in the study were sought to ensure data validity. The experts were required to have experience in qualitative research and at least two articles indexed in the science citation index on the method.

Validity, Reliability, and Rigour

To ensure the reliability of this research, the components of qualitative rigour, namely credibility, transferability, dependability, and confirmability, were considered.[23]

Credibility

Interviews were transcribed separately. An online meeting was held to review the interview records, and similarities and differences were compared with the original language. Thus, validity and reliability were assessed during data analysis. Because the research was planned for publication in international journals, the interview records were translated into English. Thus, the data were translated from Turkish into English by a team of translators, independent of the research team, to ensure the study's credibility. The Turkish and English texts were compared, and the study was finalized.

Transferability

Demographic characteristics of nurses are presented. Readers can evaluate whether it is applicable to their own studies or populations.

Dependability

Expert opinion was obtained regarding the interview questions and their content. A pilot study was conducted to ensure reliability.

Confirmability

For each interview question, follow-up questions were asked to provide clarification. At the end of the interview, a summary was provided to each nurse, and her approval was expected for control purposes. Multiple nurses provided citations to enhance confirmability.

Ethical Consideration

Permission was obtained from the Tokat Gaziosmanpaşa University Social and Humanities Studies Ethics Committee (approval no: 01-29, date: 05.11.2024) and from the relevant hospital. Written informed consent was obtained from nurses

participating in the study. The study data were shared with researchers and two experts. Data were stored on encrypted, password-protected devices. The study was conducted in accordance with the Declaration of Helsinki.

Results

58.3% of the nurses in the study were between 29 and 37 years of age, 66.6% were female, 41.6% had been health professionals for 12 years or more, and 75% had been working in the pediatric emergency services for 1 to 4 years. Of them, 83.3% were married and 75% had children (Table 1). These socio-demographic characteristics of nurses are given for transferability.

As a result of the content analysis, three main themes and six sub-themes were determined: 1) problems experienced, 2) neglected child-related sadness, 3) professional responsibility (Table 2).

Table 1. Distribution of nurses' descriptive characteristics (n=12)

Descriptive characteristic	Number	%
Age (year)		
20-28	2	16.6
29-37	7	58.3
38 and over	3	25
Average age	34.5	-
Gender		
Female	8	66.6
Male	4	33.3
Total years as a nurse		
1-4	1	8.3
5-8	3	25
9-12	3	25
12 and over	5	41.6
The years worked in the pediatric emergency services		
1-4	9	75
5-8	2	16.6
9-12	1	8.3
The average working year in the pediatric emergency service	4.0	-
Level of education		
Associate degree	2	16.6
Undergraduate degree	8	66.6
Graduate degree	2	16.6
Marital status of nurses		
Married	10	83.3
Single	2	16.6
Number of nurses who have children		
Has a child	9	75.0
None	3	25.0

Problems Experienced

Nurses stated that the addition of refugees to the country's population has led to insufficiencies in the health care system and to an increased workload. Problems faced by refugees regarding socio-economic status, language and communication, and health literacy were also emphasized. Nurses do not blame the refugees for these problems and seek to understand them empathetically.

The sub-themes of this section are increased workload, communication problems, and parents' lack of health knowledge.

Increase in Workload

Nurses stated that when refugee families and children come to the hospital, the polyclinic, and the emergency service, their workload increases. It was also noted that this situation could lead to problems, such as epidemics and increased waiting times for their patients' examinations.

I mean, I think there is a backlog, especially epidemics, births, and frankly, I think that all of them are an extra burden on our health system (P-12).

In my opinion, the intensity of polyclinic and emergency services creates excessive costs for the state and makes it difficult for our citizens to access health services (P-10).

Communication Problem

Nurses reported that language and communication deficiencies are significant factors affecting nursing care practices for children brought to the emergency unit.

Since we do not fully understand the patient's complaint due to the language barrier, we cannot adopt an appropriate approach to his illness. How will he administer the treatment we recommend at home? We cannot be certain that it is applied correctly and adequately at home (P-10).

When a person speaking a language we do not know arrives, we raise our tone of voice. We believe he understands what I am saying when I shout. When I shout, the other person does not want to express himself to me because he thinks I'm shouting in anger. This indicates a breakdown in

Table 2. Summary of qualitative analysis

Theme	Sub-themes
Problems experienced	Increase in workload
	Communication problem
	Parents' lack of health knowledge
Neglected child-related sadness	Insufficiency of socio-economic status
	Insufficiency of child care of parents
Professional responsibility	Professional awareness
	Professional ethic

communication. The words in my language have different meanings in his language, leading to a communication breakdown. Did the patient urinate? I ask her mother whether she perceives her stool, and she says she does not. I also think that was no urine output; for example, we experienced this. This is a simple example; similar examples can be generated (P-4).

It is possible that the baby has an allergic condition; the family knows about it, but because they couldn't tell us, we may have administered an allergenic drug (P-12).

Parents' Lack of Health Knowledge

They stated that parents lack healthcare information, which is why the disease processes in their children are also affected. Nurses stated that they applied appropriate care, such as nutrition, hydration, and hygiene, for preventable infectious diseases.

I think they do not know how to care for the child; that is why most of them become ill. A nutritional deficiency is present, likely because their immune resistance is low, and they nevertheless become ill. Care is lacking. Most of the parents have low educational attainment, and there is a considerable lack of knowledge (P-3).

As I said, a lack of care can lead to many illnesses, such as fever, cough, diarrhea, and vomiting. For example, they give milk to a patient with diarrhea. Why do you administer it? She says the child wanted milk; the child may want it, but she does not know that in such a case, milk should not be given (P-2).

They mainly present with infectious diseases characterized by fever, cough, and respiratory distress. Sometimes, diarrhea may predominate. Diarrhea can be severe. Our own citizens are a little more sensitive, a little more accustomed; they catch up with the slightest diarrhea, but refugees come when the work gets a little harder (P-10).

Neglected Child-related Sadness

Healthcare professionals who participated in the research reported feeling sadness and compassion because many children and families had to leave their countries and become refugees due to wars, and because, in their professional roles, they frequently encountered neglected parents and children.

The sub-theme of this section is the neglected child.

Insufficiency of Socio-economic Status

Nurses stated that child neglect occurs because of socio-economic inadequacies of refugee parents who have to change countries. Thus, they stated that they were very sad and trying to understand their traumatic experience.

Changing the state or the country is a situation that can occur only out of necessity. That's why I feel so sorry for these helpless people (P-7).

They must establish order in a country with which they are unfamiliar, both for themselves and for their children. I feel very sad and hurt, so I don't want to hurt any child as much as I can (P-6).

They originated from a specific war-affected environment. They entered illegally and did not come of their own accord; I do not think they were particularly pleased. I am compassionate, especially toward the little ones (P-12).

I contend that many of them are in disarray. When you see it, you cannot forget the condition of the children; most of them are in need of care (P-3).

Their hair is markedly unkempt, and they demonstrate inadequate personal care. Probably because they have many children, because their living conditions are poor, or, I don't know, it could be their family structure (P-1).

Insufficiency of Child Care of Parents

Nurses generally observed that families were inadequate in providing care for their children. They stated that children may develop diseases due to a lack of care. Thus, they are a highly vulnerable population who have been through an immense amount of trauma as a family; the nurse's quotes corroborate the trauma experienced by the children.

I consider this a difficult situation for people. I feel very sad, financially, morally, and psychologically, especially for the children. It is a great loss for people to lose their homes and jobs (P-9).

In general, their socio-economic status is lower; the ones I've encountered exhibit this pattern. They have very poor hygiene and suffer from associated infectious diseases; they lack adequate heating and nutrition, and their children are very weak. I think that children are also ill because of their low immunity (P-5).

Children with low body resistance are brought in for care because they are more severely malnourished. We observe that some people walk barefoot in the winter months. They experience a marked deterioration in health and subsequently develop pneumonia. Their prognosis is worse, so their recovery is delayed. Many patients present with pneumonia due to inadequate care (P-8).

Professional Responsibility

All nurses who participated in the research stated that they try to provide care for refugee families and children who come to the pediatric emergency unit as part of their professional responsibilities, without discriminating against them compared with other patients.

The sub-theme of this section is professional awareness and ethics.

Professional Awareness

It can be seen that pediatric emergency nurses fight on the front line in the struggle with such a problem and do their best in accordance with their professional awareness.

I take care of the patient; after all, he is the child. It's neither his nor the family's fault. I take care of the child when he comes here; I do everything for his health and solve the problem (P-1).

Professional Ethics

It has been stated that nurses strive, as far as possible, to fulfill their professional roles for patients in accordance with professional ethical principles.

Being a foreign national or being Turkish does not mean anything to me; I look at patients as patients and do my best (P-11).

When a child presents in an emergency, we do not discriminate among patients. We do not think of them as a Turkish citizen or the citizen of another country (P-6).

Discussion

The aim of this study was to examine the essence of the experiences, observations, and feelings of pediatric emergency nurses providing emergency care to refugee children and parents. This study also aimed to evaluate refugee children and families from nurses' perspectives. The subject was discussed in-depth with respect to the themes identified in our research. Health literacy, socio-economic status, language and communication deficiencies among refugees have been discussed in numerous studies.[24-27] The findings of our study are consistent with the literature (theme: problems experienced).

In our study, it was determined that nurses had difficulties in communication due to the different languages spoken and different cultures while caring for refugee children; they could not fully evaluate the complaints of the patients, and therefore, they were insufficient in their treatment and care practices. These system-related problems were not caused by refugees and their children. Many studies have drawn attention to the problems caused by speaking different languages in health services.[28,29] In emergency and other services, cultural, language, and health literacy problems make it potentially challenging to provide quality care for many parents.[8] Poor access to health services is considered to have detrimental consequences for the health outcomes of refugees and host populations, and may impose greater costs on the health care system in the long run. The main problems in accessing health care are linked to poor health literacy and a lack of awareness of one's right to health care; cultural and linguistic differences; protection issues due to lack of legal status; and inability to afford health services due to inadequate socio-economic status.[30] Limited health literacy disproportionately affects people of lower socio-economic status, members of minority or refugee groups, and those with limited linguistic proficiency. Insufficient health literacy was associated with higher rates of emergency room visits for non-emergency care, hospitalization and rehospitalization, and poorer health and care among children.[8,31]

Emergency room nurses provide the first line of health care communication when they perform pediatric triage on the patient. The nurses have many opportunities to engage with and support children and parents, including providing discharge and home care.[32] Ideal discharge information can maintain quality of care for a child after discharge, minimize confusion for parents, and reduce readmissions and associated family and financial barriers.[33] However, in our study we observed that health workers could not adequately fulfil their educational roles due to language barriers. Similarly, in our study, health professionals stated that, in terms of numbers, refugees strained the health care system, and these statements were presented under the relevant theme (theme: problems experienced). It has been stated that the increase in the refugee population increases hospital workload and creates organizational difficulties. Although health professionals have difficulty performing their educational roles due to language barriers and patient density, they nevertheless attempt to provide equal care to every patient according to universal/professional ethical principles, as reported in the results/themes (theme: professional responsibility and ethics).

The pediatric healthcare climate involves challenges for direct care providers who are continually exposed to both critically ill children who may be living in unhealthy circumstances and possibly facing death, and their families, who are also suffering. For other care providers, especially nurses, compassion fatigue may result in STS symptoms, decreased productivity, decreased patient satisfaction scores, job turnover, job dissatisfaction, and safety issues.[34,35] Newly arriving refugees in any location face heightened health needs related to their journey and to unhealthy environments.[36] Similarly, in our study, inadequacies among refugees in our country were identified under the theme "neglected child-related sadness". For this reason, it has been determined that they are particularly regretful about the neglect of refugee children and the difficult climate in the pediatric emergency service. These feelings are reflected in compassion fatigue, burnout, and stress among nurses related to their observations of refugees.

Study Limitations

To our knowledge, this is the first qualitative study to investigate the essence of pediatric emergency service nurses' experiences with refugee parents in Türkiye. The findings of this research provide novel and useful insights to inform practical initiatives in policy, cultural care, and interventions aimed at addressing the healthcare needs of the refugee population. Thus, mixed-methods, quantitative, or qualitative studies are needed to better understand the mechanisms underlying these conclusions. Although the results are encouraging, they cannot be generalized to other disciplines or nations.

Conclusion

We found that nurses in pediatric emergency services had significant self-reported experience in the management of pediatric emergency patients. Although there have been internal and external refugees in the past, studies examining the effect of refugees from abroad on child health remain insufficient, and more such studies are needed. Including refugees in future research should be considered.

Ethics

Ethics Committee Approval: Permission was obtained from the Tokat Gaziosmanpaşa University Social and Humanities Studies Ethics Committee (approval no: 01-29, date: 05.11.2024) and from the relevant hospital.

Informed Consent: Written informed consent was obtained from nurses participating in the study.

Footnotes

This article was presented as an oral presentation at the 3. International Congress on Biological and Health Sciences (14-16 April 2023).

Authorship Contributions

Surgical and Medical Practices: M.D.A., S.Y.A., Concept: M.D.A., S.Y.A., Design: M.D.A., G.Y., S.Y.A., D.C.Ş., Data Collection or Processing: M.D.A., G.Y., S.Y.A., D.C.Ş., Analysis or Interpretation: M.D.A., G.Y., S.Y.A., D.C.Ş., Literature Search: M.D.A., G.Y., S.Y.A., D.C.Ş., Writing: M.D.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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Case Report / Olgu Sunumu

DOI: 10.4274/cayd.galenos.2026.79058
J Pediatr Emerg Intensive Care Med 2026;13(2):117-22

Pulmonary Embolism in a Child with Klippel-Trenaunay Syndrome: A Case Report and Review of Current Guidelines

Klippel-Trenaunay Sendromu Tanılı Çocukta Pulmoner Emboli: Olgu Sunumu ve Güncel Kılavuzların İncelenmesi

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Abstract

Klippel-Trenaunay syndrome (KTS) is a rare congenital vascular disorder associated with an increased risk of thromboembolic complications, including potentially life-threatening pulmonary embolism (PE). We report a case of an 8-year-old boy with KTS who was receiving sirolimus therapy and developed fatigue, tachypnea, and hypoxemia. Echocardiography demonstrated right heart strain, and computed tomography pulmonary angiography confirmed bilateral PE. The patient was hemodynamically stable and was classified as intermediate-risk PE. Treatment with intravenous unfractionated heparin and supportive intensive care was initiated. On day 4, anticoagulation was transitioned to subcutaneous enoxaparin, with near-complete regression of right ventricular dilatation on follow-up echocardiography. He was discharged on rivaroxaban for long-term thromboprophylaxis. This case highlights the role of early echocardiography in risk stratification, the importance of conservative anticoagulation in complex vascular disorders, and individualized long-term management of pediatric patients with KTS.

Keywords: Pulmonary embolism, Klippel-Trenaunay syndrome, sirolimus, echocardiography, risk assessment

Öz

Klippel-Trenaunay sendromu (KTS), potansiyel olarak yaşamı tehdit eden pulmoner emboli (PE) dahil olmak üzere tromboembolik komplikasyon riskinin arttığı nadir bir konjenital vasküler bozukluktur. Bu yazıda, sirolimus tedavisi almakta olan KTS tanılı 8 yaşında bir erkek çocukta gelişen PE olgusu sunulmaktadır. Hastada halsizlik, taşipne ve hipoksemi gelişmiş olup ekokardiyografide sağ kalp yüklenmesi saptanmıştır. Bilgisayarlı tomografi pulmoner anjiyografi ile bilateral PE tanısı doğrulanmıştır. Hemodinamik olarak stabil olan hasta, orta riskli PE olarak sınıflandırılmıştır. Damar içi fraksiyone olmayan heparin ve destekleyici yoğun bakım tedavisi başlanmıştır. Dördüncü günde antikoagülasyon deri altı enoksaparine geçilmiş ve izlem ekokardiyografisinde sağ ventrikül dilatasyonunda belirgin gerileme gözlenmiştir. Hasta, uzun dönem tromboprofilaksi amacıyla rivaroksaban tedavisi ile taburcu edilmiştir. Bu olgu, erken dönemde ekokardiyografinin risk sınıflandırmasındaki rolünü, kompleks vasküler bozukluklarda konservatif antikoagülasyon yaklaşımının önemini ve KTS tanılı çocuk hastalarda bireyselleştirilmiş uzun dönem yönetimin gerekliliğini vurgulamaktadır.

Anahtar Kelimeler: Pulmoner emboli, Klippel-Trenaunay sendromu, sirolimus, ekokardiyografi, risk değerlendirmesi

Introduction

Klippel-Trenaunay syndrome (KTS) is a rare congenital vascular disorder characterised by the triad of capillary malformations, venous malformations, and limb hypertrophy.[1] Its most serious complications include thromboembolic events, which occur due to venous stasis, abnormal vascular structure, and localized intravascular coagulopathy. Pulmonary embolism (PE), although rare, represents a potentially life-threatening

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Received/Geliş Tarihi: 13.01.2026 **Accepted/Kabul Tarihi:** 10.03.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Balkan B, Tanyıldız M, Özden Ö, Kızılkaya MH, Oflaz Sözmen B, et al. Pulmonary embolism in a child with Klippel-Trenaunay syndrome: a case report and review of current guidelines. J Pediatr Emerg Intensive Care Med. 2026;13(2):117-22

complication in patients with KTS and may lead to pulmonary hypertension and right ventricular failure if not promptly recognized and treated.[2] In the pediatric population, PE is uncommon and often presents with non-specific symptoms like fatigue, tachypnea, or pallor.[3] In this setting, echocardiography can serve as a valuable bedside tool for early identification of right ventricular function and pulmonary hypertension prior to confirmatory imaging.[4]

We present a case of bilateral PE in a child with KTS who was receiving sirolimus therapy, highlighting the importance of early echocardiography for diagnosis, risk-stratified management in the intensive care setting, and the long-term challenges of anticoagulation in pediatric patients with complex vascular malformations.

Case Report

An 8-year-old boy with KTS, diagnosed in infancy based on extensive port-wine stains and limb asymmetry, presented with a one-week history of increasing pallor, fatigue, and tachypnea. His medical history included multiple hospitalisations for complications associated with vascular malformations. He had been on sirolimus therapy for four years to control refractory cutaneous vascular malformations, with a good clinical response.

On initial presentation, the patient exhibited tachycardia (150 beats/min), tachypnea (40 breaths/min), and hypoxemia with an oxygen saturation of 88% on room air and remained afebrile and normotensive. Physical examination was notable for bilateral coarse breath sounds, decreased in intensity over the right hemithorax. In addition, diffuse cutaneous capillary malformations were observed over the anterior and lateral aspects of the left leg (Figure 1a, b). Abdominal examination revealed localized tenderness in the right upper quadrant.

Chest radiography showed blunting of the right costophrenic angle and a basal opacity, while thoracic ultrasonography confirmed a moderate pleural effusion with atelectasis of the right lower lobe. Abdominal ultrasound revealed gallbladder wall edema, minimal ascites, and venolymphatic malformations suggestive of venous stasis or thrombosis.

Given the clinical context of KTS and pleural effusion, PE was suspected. Initial blood gas analysis demonstrated a mixed metabolic acidosis with mild respiratory compensation (pH 7.31, pCO_2 36.2 mmHg, HCO_3- 17.9 mmol/L) and an elevated lactate level (3.3 mmol/L). Cardiac biomarkers were elevated, with a high-sensitivity troponin T level of 31.3 ng/L and an N-terminal pro-B-type natriuretic peptide level of 4176 ng/L, indicating right ventricular strain. D-dimer was markedly elevated to 20.260 µg/L, strongly supporting the diagnosis of acute PE. Transthoracic echocardiography demonstrated right ventricular dilation, moderate tricuspid regurgitation, and elevated right ventricular systolic pressure (30 mmHg), consistent with right heart strain (Figure 2a, b). Computed tomography pulmonary angiography (CTPA) confirmed bilateral massive pulmonary emboli, with thrombus extending into segmental branches, and associated pulmonary infarction, right heart chamber enlargement, and right-sided pleural effusion (Figure 2c, d). Lower extremity Doppler ultrasound identified venolymphatic malformations but no deep vein thrombosis (DVT).

The patient was admitted to the pediatric intensive care unit and was initiated on intravenous unfractionated heparin (UFH) with a bolus of 50 U/kg, followed by a continuous infusion at 20 U/kg/h. Anticoagulation was monitored using both activated partial thromboplastin time and anti-factor Xa levels. Supportive management included high-flow nasal oxygen, intravenous hydration, continuous electrocardiography monitoring, and compression therapy. He remained hemodynamically stable with no indication for thrombolytic therapy. By day 4, UFH was transitioned to subcutaneous enoxaparin, with doses titrated to anti-Xa levels; the marked dilatation of the right heart chambers had

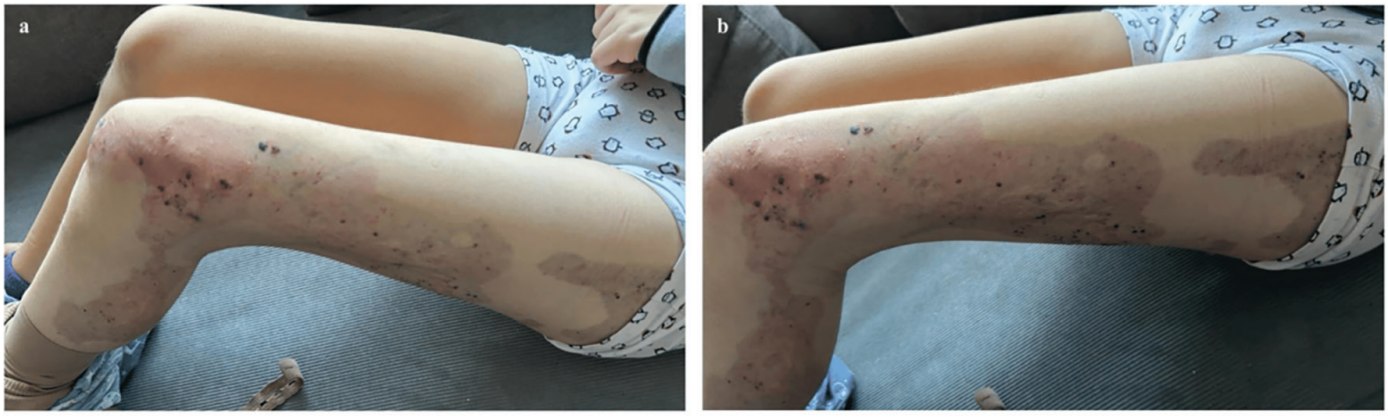

Figure 1. (a, b) Diffuse cutaneous capillary malformations on the left thigh and leg, consistent with Klippel-Trenaunay syndrome

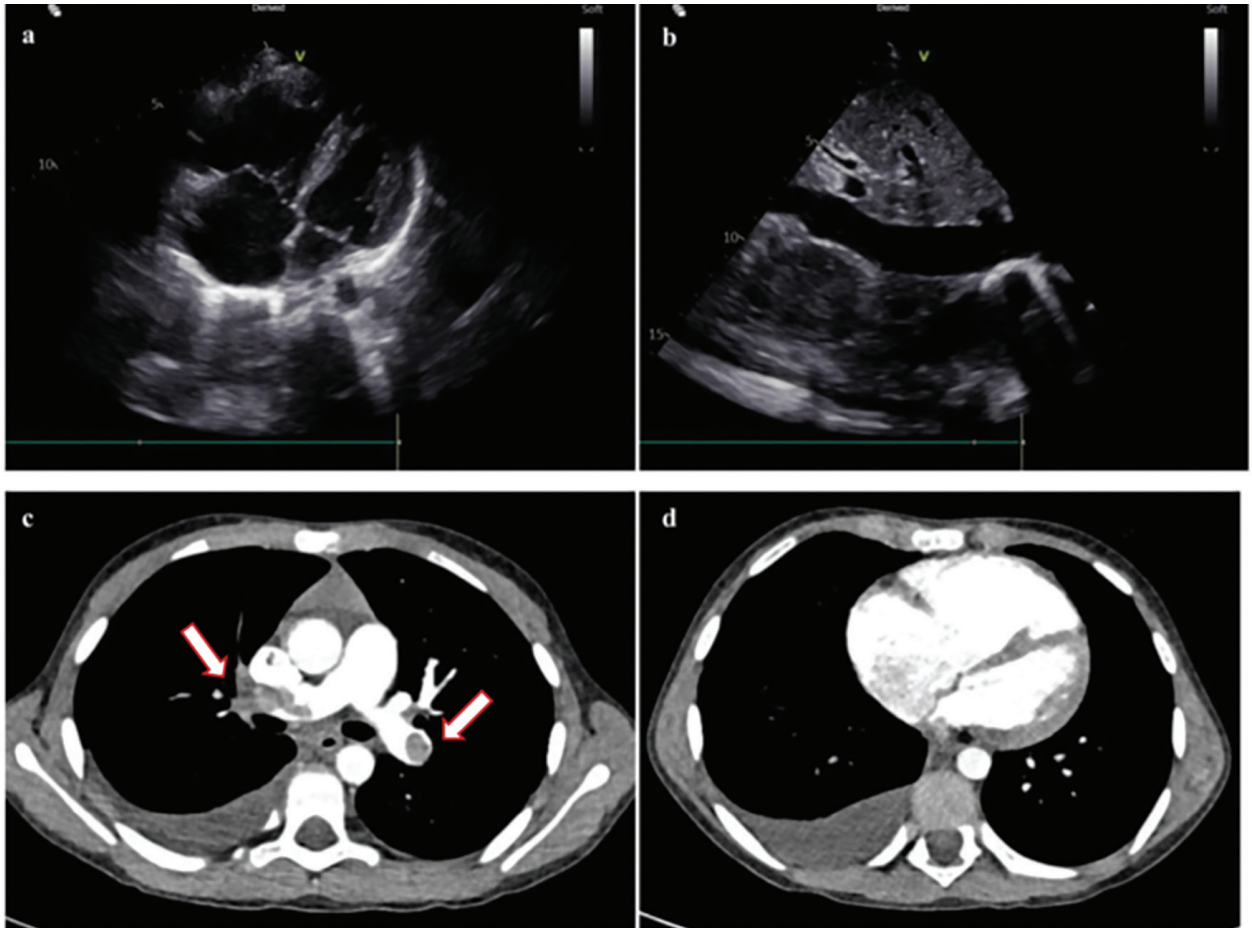

Figure 2. (a, b) Transthoracic echocardiography showing marked right ventricular dilatation and dilated inferior vena cava, consistent with right heart strain. (c, d) CT pulmonary angiography images demonstrating bilateral massive pulmonary emboli with thrombus extending into segmental branches (white arrows), enlargement of the right heart chambers, and right-sided pleural effusion
CT: Computed tomography

largely regressed to near-normal dimensions (Figure 3a, b).

The patient's respiratory status steadily improved, and he was weaned to room air by day 6. Follow-up echocardiography showed improved right ventricular function and repeat CT angiography on day 13 demonstrated significant thrombus regression and resolution of strain (Figure 3c, d). After 15 days of hospitalization, he was discharged on subcutaneous enoxaparin, with plans for long-term thromboprophylaxis with rivaroxaban. At 2-year follow-up, he remained clinically stable with no recurrence of thromboembolic events.

Written informed consent was obtained from the patient's parents for publication of this case report.

Discussion

Thromboembolic events remain a leading cause of morbidity and mortality in patients with KTS. In a large single-center retrospective series, nearly one-third of patients with KTS experienced venous thromboembolism (VTE), including both DVT and PE, highlighting the significant thrombotic burden in this population.[5] When PE is not promptly identified and treated, it may progress to pulmonary hypertension and right ventricular failure.[2] Pediatric case reports further document fatal outcomes in the absence of timely anticoagulation.[6,7] Although PE is relatively rare in children, occurring in approximately 0.14-0.9 per 100.000 in the general pediatric population, the incidence rises considerably in hospitalized settings.[8,9] Diagnostic delays are common due to the non-specific nature of presenting symptoms. Retrospective pediatric series report a median time to diagnosis exceeding seven days.[3] Our patient's presentation was consistent with these findings; symptoms had persisted for nearly a week before the diagnosis of PE.

Sirolimus, a mammalian target of rapamycin (mTOR) inhibitor targeting the phosphoinositide 3-kinase/protein kinase B/mTOR pathway, has emerged as a promising therapeutic option for refractory vascular malformations, including KTS, with reports of improved symptoms and lesion control in pediatric cohorts.[10] Recent case series have described extensive VTE occurring shortly after sirolimus initiation,

Figure 3. (a) Echocardiography showing regression of right heart chamber dilatation. (b) Improvement in right ventricular strain on follow-up imaging. (c, d) CT pulmonary angiography demonstrating a marked regression of bilateral massive pulmonary emboli extending into segmental branches (white arrows) and a reduction in right heart chamber size

CT: Computed tomography

including cases despite concurrent anticoagulation.[11] Similarly, in our patient, sirolimus therapy was associated with clinical improvement in vascular malformation-related symptoms; however, the patient developed a significant thrombotic event. Although several reports have suggested a potential association between sirolimus and thrombosis, the available evidence remains insufficient to establish a definitive causal relationship, particularly in patients with KTS.[11,12] In this population, the inherent prothrombotic state remains the primary risk factor for VTE.[1,2] Nonetheless, these observations underscore the need for vigilant thrombotic monitoring in KTS patients receiving sirolimus.

Current pediatric guidelines recommend transthoracic echocardiography as a first-line modality for initial risk stratification in suspected PE, while CTPA remains the gold standard for definitive diagnosis.[4,9] Risk stratification is clinically essential, as treatment decisions are primarily guided by the patient's hemodynamic profile. High-risk PE is defined by the presence of hypotension, shock, or cardiac arrest, whereas intermediate-risk PE refers to hemodynamically stable patients with evidence of right ventricular dysfunction or elevated cardiac biomarkers.[4] In our patient, the absence of both systemic hypotension and circulatory collapse excluded high-risk PE. However, the presence of right ventricular dysfunction on echocardiography and elevated biomarkers supported a diagnosis of intermediate-risk PE.

In intermediate-risk pediatric PE, as in our case, systemic thrombolysis or surgical thrombectomy is generally not indicated. Instead, intravenous UFH remains the first-line therapy due to its rapid onset, ease of titration, reversibility, and suitability for use in the intensive care setting. Current protocols recommend an initial bolus of 50-100 U/kg, followed by continuous infusion at 20 U/kg/h, with dose adjustments based on anti-factor Xa levels, targeting a therapeutic range of 0.35-0.7 U/mL.[4,13,14] In our patient, a lower bolus of 50 U/kg was chosen considering the underlying vascular malformation and potential bleeding risk in KTS.[1,2] This conservative anticoagulation strategy, combined with

serial echocardiography and close hemodynamic monitoring, resulted in clinical stabilization and recovery. Importantly, it avoided the potential complications associated with advanced interventions such as thrombolysis or surgical embolectomy.

Long-term secondary prophylaxis is essential in KTS due to the high risk of recurrent thromboembolic events.[5,6,15] Fatal outcomes have been reported in pediatric patients who did not receive extended anticoagulation following a first event[6] and recurrent PE has occurred despite prior thrombotic episodes.[15] Traditionally, vitamin K antagonists and low molecular weight heparin (LMWH) have been used for extended prophylaxis. However, recent studies and randomized trials have demonstrated the safety and efficacy of direct oral anticoagulants, such as rivaroxaban and dabigatran, in the pediatric population with VTE.[13] In the KTS cohort reported by Saleem et al.[5] rivaroxaban was commonly prescribed for long-term prophylaxis, supporting its role in this high-risk group. Transition from UFH to LMWH was guided by clinical stability, improvement in hemodynamics, absence of bleeding, and early echocardiographic improvement in right ventricular strain. Rivaroxaban was selected for long-term anticoagulation over vitamin K antagonists, given reports of recurrent thrombotic events in KTS and the well-recognized difficulty of maintaining stable warfarin levels in pediatric patients.[13,14] The switch occurred after clinical stabilization. This individualized, stepwise approach led to favorable outcomes, with no thromboembolic recurrence over two years.

This case highlights several key considerations in the management of pediatric patients with KTS. First, in this population, PE may present with non-specific symptoms that contribute to diagnostic delays; therefore, early echocardiography and confirmatory CTPA are essential for timely recognition and risk stratification. Second, while sirolimus therapy can improve symptoms of vascular malformations, it may increase the underlying thrombotic risk in KTS, necessitating close monitoring. Third, intermediate-risk PE can often be managed effectively with conservative, risk-guided therapy using intravenous UFH, avoiding the complications of thrombolysis or surgical intervention. Finally, long-term secondary prophylaxis remains a cornerstone of care.

Conclusion

This case emphasizes the need for heightened clinical vigilance, timely diagnostic evaluation, and risk-guided management in pediatric patients with KTS who develop PE. Careful monitoring of thrombotic risk, particularly in the setting of sirolimus therapy, and the judicious use of conservative anticoagulation strategies are central to achieving favorable outcomes.

Ethics

Informed Consent: Written informed consent was obtained from the patient's parents for publication of this case report.

Footnotes

This case was presented as an oral presentation in the Young Academy Session at the 22nd National Pediatric Cardiology and Pediatric Cardiovascular Surgery Congress, March 7-10, 2024, Antalya, Türkiye.

Authorship Contributions

Surgical and Medical Practices: M.T., Ö.Ö., M.H.K., Concept: M.H.K., Design: M.H.K., Data Collection or Processing: B.B., Analysis or Interpretation: M.T., M.H.K., B.O.S., E.Ö., Literature Search: B.B., Writing: B.B., M.T., Ö.Ö., M.H.K., B.O.S., E.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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Case Report / Olgu Sunumu

DOI: 10.4274/cayd.galenos.2026.21704
J Pediatr Emerg Intensive Care Med 2026;13(2):123-6

Can Bullying Stop a Child's Heart? A Rare Case of Commotio Cordis and Hypoxic-ischemic Encephalopathy

Çocukta Zorbalık Kalbi Durdurabilir mi? Komotio Kordis ve Hipoksik-iskemik Ensefalopatiye Nadir Bir Olgu

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Abstract

Commotio cordis is a rare but potentially fatal condition characterized by sudden cardiac arrest following blunt, non-penetrating chest trauma, most commonly in adolescent males. Mortality is particularly high when the event occurs outside organized sports settings, where delayed cardiopulmonary resuscitation (CPR) and lack of immediate defibrillation are more common. A previously healthy 14-year-old male collapsed immediately after receiving a blunt chest impact caused by peer aggression at school. Bystander CPR was initiated, and return of spontaneous circulation was achieved after 25 minutes, following multiple defibrillation attempts. Despite stabilization of cardiac rhythm in the pediatric intensive care unit, the patient developed hypoxic-ischemic encephalopathy secondary to ventricular fibrillation-induced arrest, resulting in severe, persistent neurological sequelae, including spasticity and severe motor impairment. The Glasgow Coma scale score was 5, and the modified Rankin Scale score remained 5 at follow-up. Mortality and morbidity rates are higher in non-sport-related commotio cordis cases due to delayed recognition, limited access to automated external defibrillators (AEDs), and low public awareness. Early intervention significantly impacts both survival and neurological outcomes. This case highlights the potential severity of commotio cordis triggered by bullying and emphasizes the importance of rapid resuscitative efforts. Early diagnosis, prompt CPR, and timely defibrillation reduce mortality from commotio cordis. Post-arrest neurological monitoring is crucial for managing hypoxic complications. Implementing CPR training and ensuring AED availability in schools may reduce morbidity and improve survival in non-sport-related cases.

Keywords: Commotio cordis, bullying, hypoxic-ischemic encephalopathy, cardiopulmonary resuscitation, pediatric intensive care

Öz

Komotio kordis, nadir ancak potansiyel olarak ölümcül bir durum olup genellikle ergen erkeklerde görülen, künt ve penetrasyon yapmayan göğüs travmasına bağlı ani kardiyak arrest ile karakterizedir. Olayın spor dışı ortamlarda meydana gelmesi, kardiyopulmoner resüsitasyonun (CPR) gecikmesi ve anında defibrilasyonun olmaması nedeniyle mortalitenin özellikle yüksek olduğu durumları oluşturur. Daha önce sağlıklı olan 14 yaşında bir erkek çocuk, okulda akran saldırısına bağlı göğsüne aldığı künt darbe sonrasında ani olarak yere yığıldı. Çevrede bulunan kişiler tarafından CPR başlatıldı ve birden fazla defibrilasyon girişimi sonrasında 25 dakika içinde spontan dolaşım geri döndü. Çocuk yoğun bakım ünitesinde kardiyak ritim stabilizasyonu sağlanmasına rağmen hastada ventriküler fibrilasyona bağlı arrest sonucunda hipoksik-iskemik ensefalopati gelişti; bunun sonucu olarak spastisite ve ciddi motor bozukluk gibi kalıcı nörolojik sekeller ortaya çıktı. Takipte Glasgow Koma skalası 5, modifiye Rankin skalası skoru ise 5 olarak kaldı. Spor dışı komotio kordis olgularında mortalite ve morbidite, tanının gecikmesi, otomatik eksternal defibrilatöre (AED) sınırlı erişim ve düşük kamu farkındalığı nedeniyle daha yüksektir. Erken müdahale hem hayatta kalma oranını hem de nörolojik sonucu önemli ölçüde etkiler. Bu olgu, zorbalık kaynaklı komotio kordisin potansiyel ciddiyetini göstermekte ve hızlı resüsitatif girişimlerin önemini vurgulamaktadır. Komotio kordiste erken tanı, hızlı CPR ve zamanında defibrilasyon mortaliteyi azaltır. Arrest sonrası nörolojik takip, hipoksik komplikasyonların yönetimi açısından kritik öneme sahiptir. Okullarda CPR eğitiminin uygulanması ve AED erişiminin sağlanması, spor dışı olgularda morbiditeyi azaltabilir ve hayatta kalmayı artırabilir.

Anahtar Kelimeler: Komotio kordis, zorbalık, hipoksik-iskemik ensefalopati, kardiyopulmoner resüsitasyon, çocuk yoğun bakım

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Received/Geliş Tarihi: 30.10.2025 **Accepted/Kabul Tarihi:** 15.02.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Battal F, Aydın TS, Aydın D. Can bullying stop a child's heart? A rare case of commotio cordis and hypoxic-ischemic encephalopathy. J Pediatr Emerg Intensive Care Med. 2026;13(2):123-6

Introduction

Commotio cordis is a rare yet catastrophic clinical entity defined by sudden cardiac arrest following blunt, non-penetrating trauma to the precordial region. It is most frequently in adolescent males aged 10-18 years.[1] Affected individuals typically have structurally normal hearts, with the event precipitated by the abrupt onset of ventricular fibrillation. The pathophysiological mechanism is attributed to mechanical activation of mechano-sensitive ion channels occurring during a narrow vulnerable window of ventricular repolarization, particularly the ascending phase of the T wave, which precipitates malignant ventricular arrhythmias.[2,3]

The diagnosis is primarily based on a clear temporal association between chest trauma and cardiac arrest, supported by electrocardiographic findings and the exclusion of alternative causes of sudden cardiac arrest. Notably, non-sport-related cases—including those arising from daily activities, interpersonal violence, or bullying—have been associated with significantly higher mortality rates.[4] Early initiation of cardiopulmonary resuscitation (CPR) and prompt defibrillation remain the most critical determinants of survival, as mortality may reach 80-90% in the absence of timely intervention.[5]

We report a rare case of commotio cordis precipitated by school bullying and complicated by hypoxic-ischemic encephalopathy, highlighting the potentially devastating cardiac and neurological consequences of interpersonal physical aggression in pediatric populations.

Case Report

A previously healthy 14-year-old male collapsed immediately after sustaining a blunt chest impact from a peer at school. There was no personal or family history of syncope, sudden cardiac death, inherited arrhythmia syndromes, cardiovascular disease, or substance use. School staff immediately activated emergency medical services, and the sequence of events is summarized in Table 1.

On initial assessment, the patient was pulseless. Basic life support was initiated by trained school personnel, followed by advanced life support upon the arrival of emergency medical services. Endotracheal intubation was performed, and the patient was transferred under continuous cardiac monitoring.

During transport, approximately 15 minutes after the event, ventricular fibrillation was documented. Following sequential defibrillation attempts and intravenous administration of amiodarone, return of spontaneous circulation (ROSC) was achieved after the fourth shock at minute 25 (Table 1, Figure 1).

Upon admission to the pediatric intensive care unit (PICU), the Glasgow Coma scale (GCS) score was 4 while the patient was sedated. Pupillary light reflexes were bilaterally diminished, with absent motor responses and marked spasticity, corresponding to a modified Rankin scale score of 5. Vital signs on admission were as follows: blood pressure 112/72 mmHg, heart rate 136 beats/min, respiratory rate 23 breaths/min, and oxygen saturation 97%. No external signs of thoracic trauma were observed.

Electrocardiography revealed sinus rhythm with a corrected QT interval of 0.39 seconds and no ischemic changes. Transthoracic echocardiography demonstrated a structurally normal heart with a left ventricular ejection fraction of 55%. Computed tomography of the chest, abdomen, brain, and cervical spine showed no acute pathological findings.

Laboratory evaluation revealed markedly elevated troponin T levels (651 ng/L; reference range 0-14 ng/L) and leukocytosis (20.76×10^3/μL). An arterial blood gas analysis indicated metabolic acidosis (pH 7.30; HCO_3^- 17.4 mmol/L; base excess -9.1). Other hematological and biochemical parameters were within normal limits (Table 2). The elevated troponin level was considered secondary to global myocardial ischemia related to cardiac arrest and repeated defibrillation rather than structural myocardial injury, given the absence of ischemic electrocardiographic changes and normal echocardiographic findings.

Therapeutic management included continuous lidocaine infusion (20 μg/kg/min), hyperosmolar therapy with 3% sodium chloride and mannitol, and antiepileptic treatment. Strict normothermia was maintained as part of post-cardiac arrest neuroprotective care. Serial electrocardiograms remained unremarkable, and 24-hour Holter monitoring revealed no arrhythmias.

Table 1. Timeline of clinical events and resuscitation following blunt chest trauma

Time (min)	Intervention	Details
0	Chest impact	Blunt precordial trauma due to peer bullying; immediate loss of consciousness
0-10	CPR initiated	Basic life support provided by teachers, followed by advanced life support by EMS
10	Hospital transfer	Transported to district state hospital under continuous monitoring
10-25	ACLS	Endotracheal intubation, four defibrillation attempts, intravenous amiodarone administered
25	ROSC	ROSC achieved; sinus rhythm restored

CPR: Cardiopulmonary resuscitation, ACLS: Advanced cardiac life support, ROSC: Return of spontaneous circulation, EMS: Emergency medical services

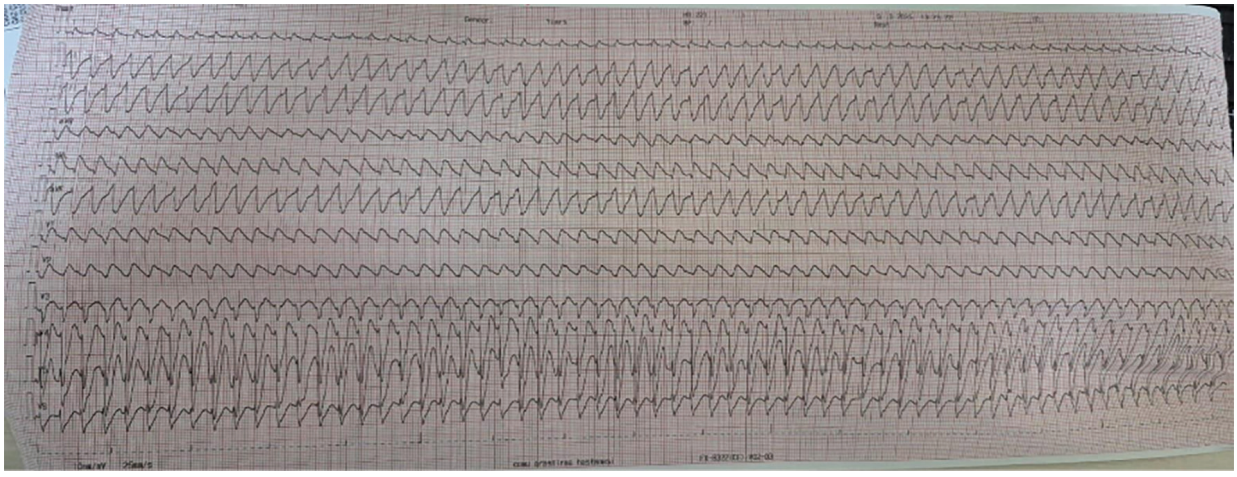

Figure 1. Electrocardiographic recording demonstrating ventricular fibrillation obtained during hospital evaluation
Continuous cardiac monitoring demonstrated ventricular fibrillation characterized by wide-complex, irregular, high-frequency electrical activity. Following sequential defibrillation, sinus rhythm was successfully restored

Table 2. Laboratory findings at PICU admission

Parameter	Result	Normal range	Comment
Hemoglobin (g/dL)	15.6	12-16	Normal
Leukocytes (×10^3/μL)	20.76	4-11	Stress-related leukocytosis
Platelets (×10^3/μL)	416	150-450	Normal
Troponin T (ng/L)	651	0-14	Elevated, likely secondary to cardiac arrest
PT (INR)	1.24	0.8-1.2	Mild prolongation
pH	7.30	7.35-7.45	Acidemia
HCO_3^- (mmol/L)	17.4	22-26	Metabolic acidosis
Base excess (mmol/L)	-9.1	-2 to +2	Base deficit

PICU: Pediatric intensive care unit, PT: Prothrombin time, INR: International normalized ratio, HCO_3^-: Serum bicarbonate

On the fifth hospital day, brain magnetic resonance imaging demonstrated diffuse T2-weighted hyperintense signal abnormalities involving the bilateral thalami, basal ganglia, and cortical gray matter, consistent with hypoxic-ischemic encephalopathy (Figure 2). Neurological improvement was limited: the GCS score increased to 5, but severe spasticity and motor deficits persisted. Despite stable cardiac function, profound neurological sequelae remained evident. A summary of the cardiac and neurological evaluations is provided in Supplementary Table 1. Written informed consent for publication of this case report and the accompanying clinical data/images was obtained from the patient's parents.

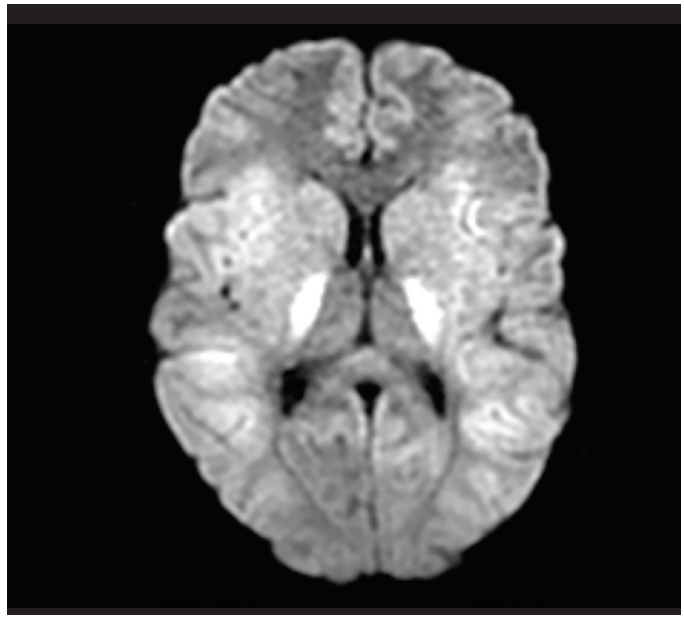

Figure 2. Cranial magnetic resonance imaging (MRI) findings
Brain MRI obtained on hospital day 5 demonstrating diffuse T2-weighted hyperintense signal abnormalities involving the bilateral thalami, basal ganglia, and cerebral cortex, consistent with hypoxic-ischemic encephalopathy

Discussion

Although commotio cordis is most commonly associated with athletic activities, approximately one-quarter of reported cases occur in non-sport settings, including routine activities, accidental trauma, and interpersonal violence.[2] These non-sport-related presentations are associated with higher

mortality, largely due to delayed initiation of CPR, limited access to defibrillation, and reduced public awareness.

The proposed pathophysiological mechanism involves a sudden increase in left ventricular intracavitary pressure at the moment of chest impact, triggering ventricular fibrillation via mechano-electric feedback.[6] Experimental models have identified a narrow vulnerability window—approximately 10-20 milliseconds during the ascending phase of the T wave—during which the myocardium is particularly susceptible to lethal arrhythmias.[3,6] Survival is highly time-dependent; CPR initiated within the first three minutes is associated with survival rates of 25-40%, whereas delays beyond three minutes reduce survival to as low as 3-5%.[2,7] In the present case, early bystander CPR and repeated defibrillation resulted in ROSC at minute 25, effectively restoring cardiac stability. However, the prolonged low-flow, hypoxic state likely contributed to severe hypoxic-ischemic brain injury, as reflected by diffuse findings on magnetic resonance imaging and persistent neurological deficits. These findings underscore that, even when cardiac recovery is achieved, commotio cordis may be complicated by devastating neurological outcomes—particularly in non-sport-related incidents where recognition and intervention may be delayed.[1]

This case expands the limited literature on bullying-related commotio cordis and emphasizes that seemingly minor interpersonal violence in school settings can result in catastrophic cardiac and neurological outcomes. Increasing CPR literacy among school personnel, ensuring widespread availability of automated external defibrillators (AEDs), and enhancing awareness of bullying-related physical trauma may be lifesaving and reduce long-term morbidity.

The neurological outcomes described are limited to the observed follow-up period, and long-term prognosis could not be fully evaluated. Advanced diagnostic investigations, including genetic testing and detailed electrophysiological studies, were not performed; therefore, underlying channelopathies cannot be entirely excluded. Nevertheless, the clear temporal relationship between chest impact and cardiac arrest, together with normal cardiac imaging and rhythm evaluation, strongly supports the diagnosis of commotio cordis.

Conclusion

Early recognition of commotio cordis, immediate initiation of CPR, and timely defibrillation are essential for reducing mortality. However, prolonged hypoxic-ischemic injury may result in irreversible neurological sequelae despite successful cardiac resuscitation, underscoring the importance of comprehensive PICU management and neuroprotective strategies. Preventive strategies, including structured CPR education and ensuring AED availability in school settings, are crucial to mitigating the impact of non-sport-related commotio cordis.

Ethics

Informed Consent: Written informed consent for publication of this case report and the accompanying clinical data/images was obtained from the patient's parents.

Footnotes

Authorship Contributions

Surgical and Medical Practices: F.B., T.S.A., D.A., Concept: F.B., T.S.A., D.A., Design: F.B., T.S.A., Data Collection or Processing: F.B., T.S.A., D.A., Analysis or Interpretation: F.B., T.S.A., D.A., Literature Search: F.B., T.S.A., Writing: F.B., T.S.A., D.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

Supplementary Table. https://d2v96fxpocvxx.cloudfront.net/1fe4afca-adad-4137-be7c-36a5e5ab6910/content-images/a5b2e7f6-0ab8-466f-9641-03b35695f996.pdf

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Case Report / Olgu Sunumu

DOI: 10.4274/cayd.galenos.2026.93824
J Pediatr Emerg Intensive Care Med 2026;13(2):127-30

Delayed Presentation of a Humerus Shaft Fracture with Bridging Callus in the Late Neonatal Period - A Diagnostic Challenge: A Case Report

Yenidoğan Döneminin Sonlarında Köprüleme Kalluslu Humerus Şaft Kırığının Gecikmiş Sunumu - Tanısal Bir Zorluk: Bir Olgu Sunumu

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Abstract

In infants, humeral fractures are commonly caused by birth injuries, child abuse, and direct or indirect trauma. After the clavicle, the humerus is the second most common site of birth-related long bone fracture in neonates and is frequently associated with forced obstetric maneuvers in difficult vaginal or cesarean deliveries. A neonate, born to a primigravida after a difficult vaginal delivery, presented on postpartum day 16 with a painless localized firm swelling in his right mid-arm noticed for 4 days. Features of abuse, fall injury, and osteogenesis imperfecta were absent. X-rays confirmed a right mid-shaft humeral fracture with bridging callus at the fracture ends. A diagnosis of a birth-associated humeral diaphyseal fracture was made. The fracture healed completely with conservative management, without sequelae. The case highlights the diagnostic challenge associated with delayed neonatal presentation of a humeral shaft fracture with callus formation.

Keywords: Pediatric humerus fractures, birth injury, difficult vaginal delivery, child abuse, fall injuries, osteogenesis imperfecta

Öz

Bebeklerde humerus kırıkları genellikle doğum travması, çocuk istismarı ve doğrudan veya dolaylı travmaya bağlıdır. Klavikula'dan sonra humerus, yenidoğanlarda doğumla ilişkili uzun kemik kırıklarının en sık görüldüğü ikinci bölgedir ve sıklıkla zor vajinal veya sezaryen doğumlarda zorlayıcı obstetrik manevralarla ilişkilidir. Zor vajinal doğum sonrası ilk gebeliğini yaşayan bir anneden doğan yenidoğan, 4 gündür fark edilen sağ orta kolunda ağrısız, lokalize, sert bir şişlikle doğum sonrası 16. günde başvurdu. İstismar, düşme yaralanması ve osteogenezis imperfekta belirtileri yoktu. Röntgenler, kırık uçlarında köprü oluşturan kallus ile birlikte sağ humerus orta şaft kırığını doğruladı. Doğumla ilişkili humerus diyafiz kırığı tanısı konuldu. Kırık, herhangi bir sekelsiz olarak konservatif tedavi ile tamamen iyileşti. Bu olgu, kallus oluşumu ile birlikte humerus şaft kırığının geç neonatal prezentasyonunun tanısal zorluğunu vurgulamaktadır.

Anahtar Kelimeler: Pediyatrik humerus kırıkları, doğum travması, zor vajinal doğum, çocuk istismarı, düşme yaralanmaları, osteogenezis imperfekta

Introduction

The humeral diaphysis accounts for 20% or less of all pediatric humerus fractures.[1] Birth trauma during vaginal breech delivery, difficult fetal extraction, and instrumented delivery (forceps or vacuum extraction), child abuse, and falls often cause humeral fractures in infants.[2,3] They are typically diagnosed soon after birth, on the first day of life or during the early neonatal period (between day 1 and day 7).[4-6] Although delayed presentation of long bone fractures in the late neonatal period (between day 8 and day 28) has been reported for the femur[7-10] and distal humerus epiphyseal injury[4,6,11] the late presentation of a diaphyseal humerus fracture with callus is rarely seen.

We report a case of a neonate, born to a primigravida after a difficult vaginal delivery, who presented on postnatal day 16 with painless swelling of the mid-portion of the right arm.

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Received/Geliş Tarihi: 06.12.2025 **Accepted/Kabul Tarihi:** 19.04.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Qureshi NA, Futela RP. Delayed presentation of a humerus shaft fracture with bridging callus in the late neonatal period - a diagnostic challenge: a case report. J Pediatr Emerg Intensive Care Med. 2026;13(2):127-30

Radiographs demonstrated a mid-shaft humeral fracture with bridging callus, posing a diagnostic dilemma. This report highlights the importance of maintaining a high index of suspicion for birth-related fractures in infants who present with unexplained limb swelling, even when the presentation is delayed. It emphasizes the need to adopt a systematic and holistic approach to differentiate birth trauma from abuse and bone fragility disorders through careful history-taking and clinico-radiological assessment.[12]

Case Report

A 15-day-old, 3.0 kg male infant, born to a primigravida, was brought to the orthopedic outpatient department (OPD) with a 4-day history of swelling in his right mid-arm. The narrative provided by his parents was as follows: the delivery was performed at a local community health center and was attended by a trained nurse. The baby cried immediately after birth. The nurse reported a difficult vaginal delivery, during which an episiotomy was performed. The parents did not notice any swelling in the baby's right arm, although they noted excessive crying since birth whenever an attempt was made to move and lift his arm passively during dressing and bathing; this crying became less frequent over time.

On day 12, the parents noticed a localized firm swelling in the child's right mid-arm. The right arm X-ray was performed, and a temporary splint was applied by a local bonesetter. On day 16, the baby was brought to the hospital's orthopedic OPD. A localized, firm-to-hard, non-tender swelling was noted in the right mid-arm, with no abnormal mobility on gentle manipulation. The capillary refill was good, with a palpable distal radial pulse. The range of motion (ROM) of the wrist, elbow, and hand was within normal limits. No wrist drop or abnormal posture of the right upper limb was observed, which ruled out a nerve injury. The other long bones, viz., the clavicle, femur, and both bones of the forearms and legs, were found to be normal. The parents denied that the child had been abused or had sustained a fall-related injury. Findings such as craniotabes, blue sclera, fractures of other long bones, multiple bony swellings, limb bowing deformities, or bruises over the body were absent on clinical examination. Radiographs demonstrated a mid-shaft humeral fracture with bridging callus. Based on a history of difficult birth and clinico-radiological findings, along with the absence of features suggestive of child abuse or fall injury, a working diagnosis of a birth-associated humeral shaft fracture was made (Figure 1).

The fracture was immobilized with a high above-elbow plaster of Paris slab for two weeks. X-rays taken after three weeks showed good alignment of the bone and an abundant callus at the fracture ends, suggesting complete union (Figure 2A-B). Follow-up at six months showed a good ROM of the shoulder and elbow. An X-ray revealed excellent remodeling of the fracture without deformity (Figure 3).

Written informed consent was obtained from the patient's parents for the publication of this case report and accompanying X-rays. The study carried out as per the World Medical Association Declaration of Helsinki.

Discussion

Humerus fractures in children are relatively uncommon and represent 2% to 5.4% of all childhood fractures.[2] Apart from birth trauma, child abuse, and fall injuries, other less common causes of neonatal humeral fractures are: neonatal osteopenia (transient neonatal osteoporosis), especially

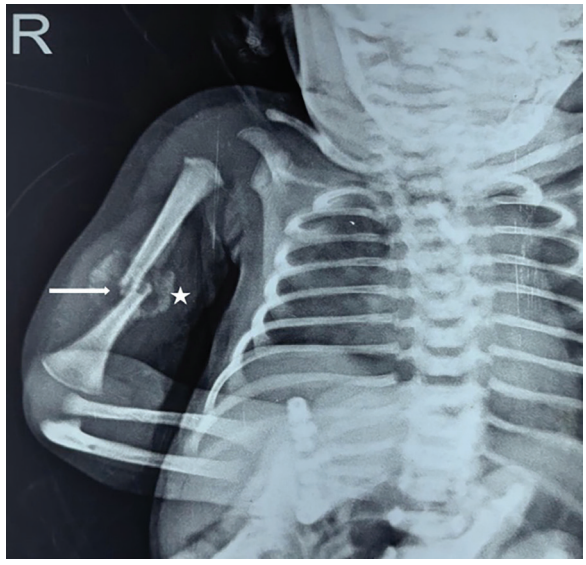

Figure 1. X-ray at 12th day after birth showing fracture mid-shaft right humerus (arrow) and bridging callus at fracture ends (asterisk)

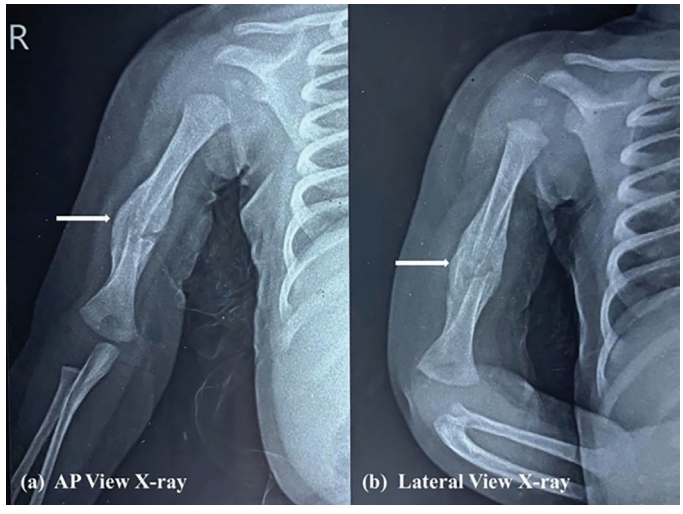

Figure 2. AP (a) and lateral (b) X-ray views of the right humerus at six weeks show abundant callus at the fracture ends, suggesting complete fracture union (arrow)
AP: Anteroposterior

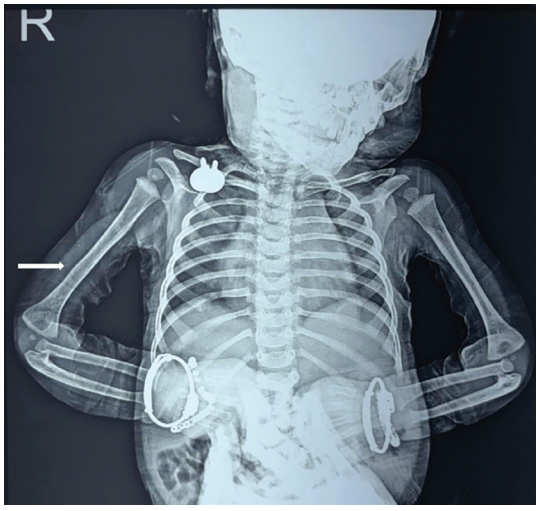

Figure 3. Follow-up X-ray after 6 months showing complete healing and excellent remodeling of the fracture mid-shaft humerus (arrow)

in preterm and low birth weight babies, bone fragility and metabolic diseases like osteogenesis imperfecta, rickets, or vitamin D deficiency, leading to secondary osteopenia and fractures.[4] Neonates, who are diagnosed with a fracture in the first week of life, in the absence of known postnatal trauma, are considered to have a birth fracture.[2,3,5] Humerus fracture is the second most common birth-related long bone fracture in neonates, after the femur, with a reported incidence of 0.04-0.2/1000 live births.[3,5,6] Breech presentation, external version, difficult delivery, inadequate uterine relaxation, prematurity, and osteogenesis imperfecta are some risk factors associated with neonatal long bone fractures involving the humerus and femur shaft.[5,12] Traction on the extended arm in breech presentation, and axillary traction to disengage an impacted shoulder, as in shoulder dystocia in cephalic presentation, can cause fracture of the humerus shaft during vaginal deliveries.[13]

Most neonatal humeral shaft fractures are transverse and occur at the mid-third level[2,13] as in our case. Their diagnosis is usually straightforward and almost always established by plain X-rays.[6] A history of difficult labor, a pathognomonic "click" or "snap" during obstetric maneuvers, and a characteristic clinical presentation help in diagnosing the fracture immediately after delivery, on the first day of life, or in the early neonatal period (between day 1 and day 7).[4,5,12] Delayed presentation of long bone birth fractures in the late neonatal period has been reported for the femur and distal humerus epiphyseal injuries; however, the late presentation of a diaphyseal humerus fracture with callus in neonates is rarely seen. Al-Habdan[7] reported a delay of 3 to 7 days in 48.0% of neonates with long bone fractures; Morris et al.[8] reported three neonates with delay of 7, 10, and 21 days. While Kanai et al.[9] and Toker et al.[10] diagnosed birth-associated femur fracture on postpartum days 9 and 10, respectively; Jacobsen et al.[11] diagnosed distal humeral epiphysis injuries between 9 and 30 days after birth in the majority of their patients.

An important differential diagnosis of humeral diaphyseal fractures in children younger than 3 years, and particularly <6 months, is child abuse.[1-3] The presence of a "corner" or "bucket-handle fracture of the metaphysis", on radiographs is pathognomonic of child abuse.[1,2] Other characteristic findings strongly suggestive of child abuse include the presence of fractures in the long bones and ribs with callus at different stages of healing, fracture of the scapula or the sternum,[1,2] and patterned bruises of different ages in covered areas such as the chest, abdomen, buttocks, and lower back.[14] Another common differential cause of bone fragility in neonates simulating child abuse is osteogenesis imperfecta and metabolic bone disease of prematurity.[2,15] Osteogenesis imperfecta is characterized by the presence of abnormal type 1 collagen and defective mineralization of the bone matrix, resulting in the generation of mechanically weak bones with a propensity to fractures.[15] The classical blue sclera in a neonate, with a maternal history of previous multiple miscarriages and intrauterine deaths, and a family history of recurrent fractures following minor trauma, provides an important clue to the diagnosis.[15] Genetic and biochemical assays are useful to confirm the disease.[2]

While humeral fractures in children, particularly those <6 months old, are often linked to child abuse, fall injuries are usually associated with humerus fractures in children between 6-12 months.[3] The characteristic features of bone disease in infancy, such as craniotabes, a large anterior fontanel, sutural diastasis without hydrocephalus, and frontal bossing, were absent in our case.[15] In addition, the absence of a maternal history of recurrent spontaneous abortions or intrauterine deaths, the absence of blue sclera, the absence of multiple fractures in other long bones, and parental denial of abuse or fall injury, together with a history of difficult vaginal delivery with episiotomy, favour the diagnosis of a birth-related humeral fracture in this neonate.

The treatment of neonatal humerus shaft fractures is mostly non-operative and includes simple chest bandage, sling-and-swathe, von Rosen splint, U-slab, above-elbow slab or cast, and swaddling.[1,6] Immobilization of the limb,[12] for approximately two weeks is generally sufficient.[5,6] Despite an initially unsatisfactory appearance of fracture union on X-rays, remodeling of significant malalignment of up to 40-50% or greater can be seen within 1 to 2 years.[1]

Conclusion

In conclusion, this case report describes the diagnostic dilemma that resulted from the delayed presentation of a humerus shaft fracture with bridging callus in the late neonatal period. Although birth-related trauma is a frequent cause of neonatal humeral diaphyseal fractures, the possibility of child abuse, metabolic diseases, and fall injuries must be ruled out. A proper history from the parents, a thorough clinical examination of the neonate, biochemical analysis, and radiographs are the cornerstones of diagnosis. Obstetricians must take appropriate care when applying traction to the limbs during fetal extraction in vaginal deliveries. These fractures have an excellent prognosis and heal completely with limb immobilization, without sequelae.

Ethics

Informed Consent: Written informed consent was obtained from the patient's parents for the publication of this case report and accompanying X-rays.

Acknowledgements: We acknowledge parents for giving consent for publication. We also acknowledge Dr. Karan Sapra for assisting us in data collection during follow-up of the patient.

Footnotes

Authorship Contributions

Surgical and Medical Practices: R.P.F., Concept: N.A.Q., R.P.F., Design: N.A.Q., Data Collection or Processing: N.A.Q., Analysis or Interpretation: N.A.Q., Literature Search: N.A.Q., Writing: N.A.Q.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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DOI: 10.4274/cayd.galenos.2026.93695
J Pediatr Emerg Intensive Care Med 2026;13(2):131-8

Increased Intracranial Pressure Syndrome

Kafa İçi Basınç Artışı Sendromu

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Abstract

Increased intracranial pressure syndrome (IIPS) is a condition in which intracranial pressure (ICP) rises above the upper limit of normal for age, leading to the development of symptoms and signs. Under normal conditions, the average ICP is 1.5-6 mmHg in infants, 3-7 mmHg in children, and 5-15 mmHg in adults. IIPS is defined as ICP remaining above 20 mmHg for more than 5 minutes. ICP may increase in the presence of increased blood, cerebrospinal fluid and brain tissue volume within the skull, or in the presence of space-occupying lesions. The purpose of this protocol is to provide pediatricians with general information on the diagnosis, monitoring, and treatment of ICP. This protocol does not replace the professional opinion of the physician.

Keywords: Cerebral edema, increased intracranial pressure, traumatic brain injury, pediatric intensive care

Öz

Kafa içi basınç artışı sendromu (KİBAS); kafa içi basıncının yaşa göre normal değerin üst sınırının üstüne çıkması, buna bağlı semptom ve bulguların gelişmesi durumudur. Normal koşullarda ortalama intrakranial basınç (İKB) infantlarda 1,5-6 mmHg, çocuklarda 3-7 mmHg, yetişkinlerde 5-15 mmHg'dır. İKB'nin 20 mmHg'nın üzerinde 5 dakikadan daha uzun seyretmesi durumunda artmış İKB'den söz edilir. Kafatası içinde; kan, BOS ve beyin dokusu hacminin artması veya yer kaplayıcı lezyon varlığında İKB yükselebilir. Bu protokolün amacı KİBAS'ın tanısı, takibi ve tedavisi konusunda çocuk hekimlerine genel bilgi vermektir. Bu protokol, hekimin profesyonel görüşünün yerine geçemez.

Anahtar Kelimeler: Serebral ödem, kafa içi basınç artışı, travmatik beyin hasarı, çocuk yoğun bakım

Introduction

Increased intracranial pressure syndrome (IIPS) is a condition characterized by an increase in intracranial pressure (ICP) above the upper limit of the age-specific normal range, accompanied by the development of associated symptoms and findings.[1,2] Under normal conditions, the average ICP is 1.5-6 mmHg in infants, 3-7 mmHg in children, and 5-15 mmHg in adults.[1] A sustained ICP above 20 mmHg for more than 5 minutes is considered elevated ICP.[2] However, measuring and interpreting ICP in children is challenging. Numerous factors must be considered, including the child's age, the method of measurement, the child's position during measurement, whether the child is crying, whether sedation was administered, and the child's body mass index.[3] The upper limit of ICP measured via lumbar puncture (LP) is generally accepted as 20 mmHg. Although cerebrospinal fluid (CSF) pressure measured during LP correlates with ICP, it may not always provide an accurate indication. This is because

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Received/Geliş Tarihi: 01.07.2025 **Accepted/Kabul Tarihi:** 15.01.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Kocaoğlu Ç, Çıtak A, İnceköy Girgin F, Kamit F, Uysal Yazıcı M, et al. Increased intracranial pressure syndrome. J Pediatr Emerg Intensive Care Med. 2026;13(2):131-8

numerous factors—such as the patient's position, whether sedation was administered, the type of medication used if sedation was given (ketamine may increase CSF production and thereby raise pressure), pain perception, and whether the patient performs a Valsalva maneuver—can influence the CSF pressure measured during LP.[3] The general consensus is that it is more appropriate to evaluate the patient not solely based on ICP but in conjunction with other clinical findings.[2]

Although it is connected to the neck via the foramen magnum and other small foramina, the intracranial space can be conceptualized as a closed box. Approximately 80% of the intracranial space is occupied by brain tissue, 10% by CSF, and 10% by blood (Figure 1).

According to the Monro-Kellie doctrine, the cranium is not flexible. The combined volumes of blood, CSF, and brain tissue maintain a constant intracranial volume. An increase in one of these components or the presence of a space-occupying lesion is compensated for by a decrease in the others (Figure 2).

Within the skull, an increase in the volume of blood, CSF, and brain tissue or the presence of a space-occupying lesion leads to an elevation in ICP. Cerebral venous sinus thrombosis, masses in the upper mediastinum, and conditions compressing the jugular veins result in cerebral venous stasis by impairing venous return. An increase in cerebral blood volume results in increased ICP (Figure 3). ICP may also develop in cases of meningitis and subarachnoid hemorrhages, where obstruction of CSF flow or impaired absorption leads to CSF accumulation and increased ICP. It has been demonstrated that CSF production rate in adults and older children is approximately 20 mL/hour or 500 mL/day.[4] On the other hand, a study by Page et al.[5] reported that CSF production in children under 8 years of age is approximately 15 mL/hour.

Diffuse cerebral edema develops in conditions such as ischemic or anoxic events, acute liver failure, hypertensive encephalopathy, and Reye's syndrome, whereas brain tumors, cerebral infarction, hematoma, and cerebral abscess typically cause localized cerebral edema. Cerebral edema results in an increase in brain tissue volume and in IIPS.

IIPS Reasons

Intracranial space-occupying lesions (tumor, cyst, hematoma, abscess), increased CSF volume (hydrocephalus, meningitis), vasogenic cerebral edema (trauma, tumor, abscess, hypertension, pseudotumor cerebri), cytotoxic cerebral edema (cerebral infarction/ischemia, hypoxia), and osmotic cerebral edema (electrolyte imbalance, inappropriate antidiuretic hormone secretion) are mechanisms that contribute to increased ICP. These mechanisms can cause ICP, alone or in combination (Table 1). However, temporary increases in ICP

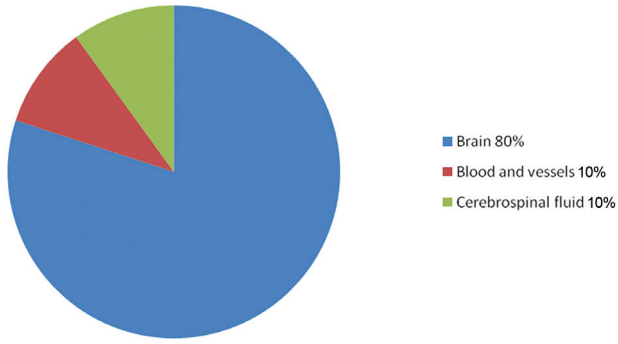

Figure 1. Components filling the intracranial space

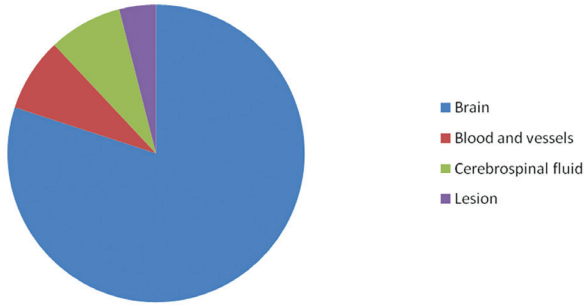

Figure 2. Intracranial components in the compensation phase

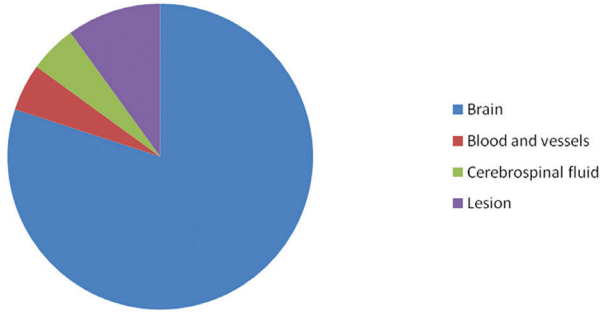

Figure 3. Intracranial components in the decompensation phase

Table 1. IIPS reasons

Head trauma (subdural, epidural, subarachnoid, intraparenchymal hemorrhages)
Cerebral edema (infarction, ischemia, hypoxia)
Diffuse axonal injury
Aneurysm rupture
Arteriovenous malformations
Increased cerebrospinal fluid production or impaired cerebrospinal fluid circulation (hydrocephalus)
Central nervous system infections (encephalitis, meningitis, abscess)
Intracranial space-occupying lesions (tumor, cyst, hematoma, abscess)
Vasculitides (microscopic polyangiitis)
Hypertensive encephalopathy (posterior reversible encephalopathy syndrome, etc.)

may occur during physiological events such as sneezing, coughing, straining, or the Valsalva maneuver.

Physiopathology

One or more of the following mechanisms may cause an increase in ICP. An increase in ICP can lead to compression of brain tissue, impaired perfusion, and brain cell damage.

1. Cerebral edema resulting from cellular damage and disruption of the blood-brain barrier.
2. Decreased vascular tone due to impaired autoregulation.
3. Impaired CSF circulation.
4. Increased CSF production in response to cerebral inflammation.
5. Vasodilation and increased cerebral blood flow (CBF) secondary to hypercapnia or hypoxia.

Inappropriate head and neck positioning, improper administration of sedation and analgesia, electrolyte imbalance (hyponatremia), and low blood oncotic pressure (hypoalbuminemia) also contribute significantly to cerebral edema. However, cerebral edema is the primary mechanism underlying the development of IIPS. There are three types of cerebral edema.

• Cytotoxic or cellular edema is intracellular edema resulting from mechanical damage to the cell membrane. This edema, which appears within minutes of trauma, is primarily caused by dysfunction of the Na-K ATPase. The uncontrolled influx of sodium into the cell, followed by the entry of water, leads to intracellular edema. This form of edema is common in patients with brain injuries such as traumatic brain injury, traumatic axonal injury, or hypoxic-ischemic injury. In these injuries, brain cells can sustain severe damage.

• Vasogenic edema: Increased permeability of capillary endothelial cells causes fluid to pass into the extracellular space. Neurons are not primarily injured. Vasogenic edema is observed in tumors, intracranial hematomas, infarcts, abscesses, and central nervous system infections. Since neurons are not primarily injured, treatment aimed at reducing edema may prevent secondary ischemic injury to the surrounding brain tissue. In this context, steroid therapy may be beneficial in treating vasogenic edema that forms around mass lesions.

• Interstitial edema is characterized by increased fluid in the periventricular white matter. As in hydrocephalus, increased CSF volume is the most common cause of elevated hydrostatic pressure. Interstitial edema responds to treatments that reduce CSF pressure.

Brain Elasticity and Compliance

Brain elasticity represents the increase in ICP per unit increase in intracranial volume and is denoted by "dP/dV". High elasticity indicates that a small change in volume will result in a significant change in ICP. Compliance, on the other hand, is the inverse and is denoted by "dV/dP". Compliance reflects the skull's elasticity-in other words, its ability to absorb pressure changes. Intracranial elasticity (dV/dP) is non-linear. In the early stages of the pathological process, increases in parenchymal volume minimally affect ICP. Once compensatory mechanisms are exhausted, even small increases can significantly elevate ICP.

Pressure-volume Index (PVI)

The PVI is defined as the increase in pressure observed when 1 mL of normal saline is infused into the ventricle via an intraventricular catheter. In children, the normal PVI values vary with age but average 0-2 mmHg/mL. Values of 4 mmHg/mL or higher indicate low cerebral compliance.

Cerebral Perfusion Pressure (CPP)

The perfusion pressure of any tissue depends on the difference between systemic arterial pressure and venous pressure within the vascular bed of that tissue. The intracranial venous pressure within the dural sinuses is approximately equal to the mean arterial pressure (MAP). In practice, CPP is calculated using the following formula:

CPP=MAP-ICP

(MAP=2/3 diastolic pressure+1/3 systolic pressure)

In an ischemic brain region, a decrease in CPP increases brain damage, while an increase in CPP protects brain tissue from the effects of ischemia. However, an excessive increase in CPP may raise the risk of hemorrhage. The lower limit of CPP is generally accepted as 40 mmHg, and pressures below this level have been associated with increased mortality.[6,7] In contrast, there is not a full consensus regarding the upper limit of CPP. Different threshold values have been established across various studies based on age groups.[6,7] Although the optimal CPP is not definitively known, a range of 50-60 mmHg is generally accepted as normal. To maintain CPP, the MAP must be between 50 and 150 mmHg. At pressures >150 mmHg, hydrostatic edema may develop, leading to increased ICP. Conversely, in various diseases of the central nervous system, increased mortality and morbidity have been reported at values below this threshold.[6] Studies suggest that using CPP rather than ICP monitoring is more appropriate for patient follow-up and treatment planning.[8]

CBF

CBF refers to the volume of blood reaching the brain within a given time interval. Under normal conditions, the blood flow to the brain in a healthy adult is 750 mL/min. This volume accounts for approximately 15% of the blood pumped by the heart in one minute. In this case, the average blood flow is 50-

54 mL/min per 100 mg of brain tissue (50-54 mL/min/100 g). CBF depends on many factors. One of these is blood viscosity. In addition, factors such as blood vessel diameter and CPP affect blood flow.

The partial pressure of oxygen (PaO_2) in arterial blood affects cerebral perfusion. An increase in PaO_2 causes vasoconstriction, while a decrease causes vasodilation. Conversely, an increase in the partial pressure of carbon dioxide ($PaCO_2$) in arterial blood (hypercapnia) leads to cerebral vasodilation and increased CBF, while a decrease in $PaCO_2$ (hypocapnia) causes vasoconstriction.

Autoregulation

CBF is regulated by a physiological adaptation mechanism that maintains constant blood flow in response to changes in perfusion pressure, independently of metabolic increases. Cerebral circulation is primarily regulated by metabolic and chemical stimuli, perfusion pressure, and neural stimuli. Thus, CBF is maintained, and the brain's active regions are protected with increased blood supply.[9]

Symptoms and Findings

The clinical presentation of elevated ICP varies depending on the child's age and whether the pressure increase is gradual or acute. For example, in infants, if IIPS rises gradually, macrocephaly and bulging fontanelles may be prodromal signs, whereas in acute IIPS, severe headache, vomiting, and altered mental status are the prominent clinical features. Additionally, certain symptoms and findings specific to the underlying condition causing IIPS may accompany the syndrome. The approach to IIPS is outlined in the algorithm.

The three key findings of IIPS are bradycardia, hypertension (increased pulse pressure), and irregular breathing. This is referred to as the "Cushing triad". Additional symptoms and findings include headache, nausea, vomiting, altered consciousness, papilledema, and symptoms related to cranial nerves (most commonly diplopia, anisocoria, and impaired eye movements associated with pathologies of the 2nd and 6th cranial nerves). Other common findings may include abnormal gait and coordination disorders. Additionally, papilledema on fundoscopic examination may be a specific indicator of elevated ICP.

In children with suspected high ICP, LP carries a risk of cerebral herniation. Therefore, in children with clinical suspicion (cerebral edema, space-occupying lesions, or obstructive hydrocephalus, etc.), an LP should not be performed until neuroimaging is conducted to identify conditions that may constitute contraindications.[10]

Radiological Imaging in IIPS

The diagnosis of IIPS is established based on the clinical presentation and neuroimaging. However, radiological findings may take time to become apparent. Even if the patient develops an acute increase in ICP, the appearance of radiological findings may be delayed by up to 24 hours.[11] Due to its ease of access in emergency settings, computed tomography (CT) of the brain is the preferred imaging method in the initial phase. CT is also the preferred imaging modality for the initial assessment of intracranial injuries caused by head trauma. However, magnetic resonance imaging (MRI) is superior to CT in identifying signs of increased ICP. Its disadvantages include reduced accessibility and a longer procedure time compared to CT.

The following findings may be detected in cranial imaging:

- Midline shift
- Obliteration of the basal cisterns
- Blurring of the sulci
- Enlargement of the optic nerve sheath diameter (ONSD)
- Findings related to the primary pathology causing ICP elevation (brain edema, intracranial mass, hemorrhage, etc.).

Repeat brain imaging (CT or MRI within 12 to 24 hours). If there is no change in the patient's condition, routine repeat imaging is not necessary. However, if there is a deterioration in the patient's level of consciousness (decrease on the Glasgow Coma scale), changes in pupil size (anisocoria, strabismus), new neurological findings, focal deficits, if the patient has a history of head trauma, if a space-occupying lesion is present on the initial CT, or if ICP monitoring cannot be performed, repeat central imaging may be appropriate.[12,13]

Monitoring of IIPS

Even with appropriate treatment, If IIPS is not properly monitored, it may lead to herniation. In such cases, the following symptoms and signs may appear:

- Worsening headache
- Altered level of consciousness
- Unilateral pupil dilation (anisocoria)
- Third cranial nerve palsy
- Decerebrate posture
- Respiratory irregularities
- Cardiac arrest

Various Methods are Used for ICP Monitoring

- To detect increases in ICP, pressure should be monitored using a probe placed in the lateral ventricle by a neurosurgeon (evidence level III).[6] The goal is to maintain ICP below 20

mmHg. In cases where ICP monitoring is not possible, the patient can be monitored using repeated brain CT scans.

• The ONSD can be measured using ultrasound. There are limited studies supporting age-based normal values.[14,15] The normal ONSD value is 2.1-4.0 mm in children under one year of age and 2-3 mm in children over one year of age.[12] Although there is no complete consensus on the upper limit for ONSD, upper limits of 5 mm for adults, 4.5 mm for children, and 4 mm for infants are generally accepted.

• Jugular venous oxygen saturation (SvO_2) is a monitoring method used to track changes in CBF and cerebral oxygen consumption.[16] Continuous SvO_2 is measured using a fiber-optic catheter placed in the right jugular vein. The physiological upper limit of jugular SvO_2 is 55%. Values below this threshold indicate reduced CBF secondary to decreased CPP or to vasoconstriction associated with hyperventilation. It indicates that CBF is insufficient to meet the demand. Conversely, elevated SvO_2 indicates mitochondrial dysfunction, reduced demand due to cell death, or increased CBF.[16]

• If brain tissue oxygenation ($PbrO_2$) monitoring is used, maintaining a $PbrO_2$ level above 10 mmHg is recommended. The level of evidence is low. The use of $PbrO_2$ monitoring should be limited to patients without contraindications to invasive neuromonitoring, such as coagulopathy, and patients without a diagnosis of brain death (evidence level III).[6]

• Near-infrared spectroscopy (NIRS) is a technique that measures the transmission and absorption of near-infrared light (700-1000 nm). The different transmission and absorption properties of oxygenated and deoxygenated hemoglobin enable NIRS to monitor brain oxygenation. It operates on the principle of collecting the transmitted infrared light using a receptor and measuring differences in wavelength. It provides information about brain oxygen saturation.

Among the monitoring methods mentioned above, the gold standard is ICP monitoring using a probe placed in the lateral ventricle. However, it requires an invasive procedure and faces challenges regarding applicability across settings. In recent years, measuring ONSD using ultrasound—which does not require an invasive procedure and can be performed at the patient's bedside—has increasingly become the preferred method.[17,18] Although it may require experience, it yields highly consistent results when performed by experienced practitioners.

NIRS is also a non-invasive method, but there may be issues regarding measurement consistency. It may be a more appropriate approach to make decisions based on the trend of increase or decrease rather than the numerical measurement value.[19]

Treatment

The primary goal in the treatment of IIPS is to eliminate the underlying cause. However, this may not always be possible. In such cases, IIPS is treated with a series of palliative measures aimed at reducing or halting the progression of ICP. A significant portion of brain damage resulting from head trauma does not occur at the moment of injury, but rather develops in the hours or days following the trauma. The goal of ICP management is to prevent or minimize secondary damage. In addition to treatment aimed at reducing ICP, maintaining adequate ICP is important for reducing the patient's morbidity. Limited observational evidence suggests that the target ICP in children should be age-specific as follows.[6,7]

CPP 0-5 years: 40-50 mmHg

CPP 6-17 years: 50-60 mmHg

Although the treatment approaches for IIPS may vary depending on the underlying cause, they are generally consistent. Therefore, IIPS treatment will be examined under the subheadings general measures and the approach to traumatic IIPS.

Note: Evidence levels for some treatment recommendations are provided below. The levels of these evidence grades are as follows:

Level I recommendations are based on high-quality evidence.

Level II recommendations are based on moderate-quality evidence.

Level III recommendations are based on low-quality evidence.

General Measures

• Maintaining stable vital signs—particularly avoiding hypotension, ensuring adequate oxygenation, and preventing hypercapnia—is a measure that helps prevent brain tissue damage from secondary causes. To this end, adequate fluid support and, if necessary, the initiation of vasopressors, should be considered.

• Elevating the head helps reduce ICP. Generally, elevating the head at a 30-degree angle is appropriate.[20] Excessive elevation is not recommended, as it may impair cerebral perfusion. When positioning the patient, care must be taken to ensure that not only the head but also the entire body are elevated on a ramp. Maintaining the head in a neutral position is recommended to facilitate CBF. A cervical collar may be applied if necessary. However, caution is required concerning the development of occipital pressure ulcers in patients who remain in this position for extended periods.

• Since glucose is the brain's primary energy source, hypoglycemia must be prevented.

• Anemia should be avoided, as it may impair oxygen delivery to the brain. Discussions regarding the hemoglobin threshold

for determining the ideal level and transfusion requirements are ongoing. In most studies, transfusion is recommended for hemoglobin levels below 7 g/dL, and a restrictive transfusion strategy is advised.[21,22] However, the 7 g/dL threshold does not apply to premature infants, children with severe hypoxia, hemodynamic instability, active blood loss, or cyanotic heart disease.[21] Indeed, a meta-analysis published in 2021 states that "hemoglobin concentration may not be the most informative indicator of transfusion need in patients with different physiological adaptations to anemia".[22] Therefore, making decisions on a case-by-case basis is more appropriate.

• If the patient is at risk of seizures, prophylactic anticonvulsants should be initiated. In cases of sudden-onset seizures, benzodiazepines remain the first choice. However, monitoring the patient's level of consciousness may be challenging. Recent publications offer cautious recommendations regarding seizure prophylaxis.[6,23] While phenytoin was previously the first-line choice, levetiracetam has been used more frequently in recent years. However, there is insufficient evidence to recommend levetiracetam over phenytoin based on efficacy in preventing seizures or toxicit.[6]

• In intubated patients, hyperventilation was previously recommended. However, it is no longer recommended because it reduces CBF and impairs cerebral perfusion. The recommended arterial pCO_2 level in the latest guidelines has been updated to 35-45 mmHg.[6] High positive inspiratory pressure and high positive end-expiratory pressure should be avoided provided that oxygenation remains adequate. There are no studies regarding the temporary application of hyperventilation in children with a risk of herniation or an ICP crisis.[6]

• Sufficient sedation (midazolam) and analgesia (fentanyl) must be provided to allow for controlled ventilation in intubated patients. If ICP remains high despite adequate sedation, neuromuscular blockade may be required. Rocuronium bromide or vecuronium bromide may be used for this purpose. However, monitoring for seizures via bedside EEG may be necessary.

• Since endotracheal aspiration may stimulate the gag reflex and lead to an increase in ICP, administration of lidocaine hydrochloride at 1-2 mg/kg via the endotracheal or intravenous route prior to aspiration is recommended. However, this effect is short-lived (<10 min). Lidocaine hydrochloride suppresses the gag reflex by blocking the superior laryngeal nerve and the glossopharyngeal nerve.

• While prophylactic moderate hypothermia (32-33 °C) is not recommended to improve overall outcomes (mortality, morbidity, functional loss) (evidence level II), moderate hypothermia is recommended for ICP control (evidence level III).[6]

Hyperosmolar Therapies

• Hypertonic saline (3% NaCl solution) is administered by infusion at a dose of 2-5 mL/kg over 10-20 minutes (evidence level II).[6] The goal is to increase serum osmolarity. This may be repeated 4-6 times daily, depending on the patient's serum sodium level. Sodium levels can be monitored via blood gas analysis before hypertonic saline infusions (4-6 times daily). Additionally, serum sodium levels should be checked twice daily in the biochemistry laboratory. A very rapid rise in serum osmolarity and exceeding 360 mmol/L should be avoided (evidence level III).[6,24] Generally, maintaining the patient's serum sodium level between 150-160 mEq/L is sufficient. If the serum sodium level rises above 160 mEq/L, there is a risk of anemia, thrombocytopenia, and deep vein thrombosis. Hypertonic saline is also administered as a continuous infusion at a dose of 0.1-1.0 mL/kg/hour (evidence level III).[6] Neither approach is superior to the other. Unlike mannitol, 3% hypertonic saline does not cause severe osmotic diuresis and carries a low risk of hypovolemia and renal failure. For this reason, it is preferred over mannitol in pediatric applications. However, complications associated with hypertonic saline administration include hypernatremia, hyperosmolality, acute kidney injury, heart failure and/or pulmonary edema due to fluid overload, metabolic acidosis, and osmotic demyelination syndrome (central pontine demyelination). Although rare, a rebound increase in ICP may be observed following hypertonic saline administration.

• Mannitol solution is administered via infusion at a dose of 0.5-1 g/kg over 20-30 minutes. The preparation contains 20% mannitol. The maximum dose for children should not exceed 100 g or 500 mL. It can be administered every four hours, provided that serum osmolality is monitored before each mannitol dose. Rapid increases in serum osmolality and levels exceeding 320 mmol/L should be avoided (evidence level III).[6,24] Additionally, since mannitol causes rapid diuresis, urine output should be monitored, and a urinary catheter should be placed if necessary to prevent bladder distension. Mannitol administration is also associated with potential side effects such as hyperosmolarity, hypovolemia, electrolyte imbalance, and acute kidney injury. Therefore, serum electrolytes and renal function tests should be closely monitored in patients receiving mannitol. It should not be administered via continuous infusion, because when neuronal cells are exposed to a hypertonic environment for prolonged periods, neuronal shrinkage occurs and the cells compensate by increasing intracellular osmolarity to return to their normal size. This situation gradually reduces mannitol's efficacy and may lead to rebound neuronal swelling.[25]

Corticosteroids

Although corticosteroids have been shown to be beneficial in preventing ICP elevation resulting from vasogenic edema associated with brain tumors, they are not recommended in cases of ischemic or hemorrhagic events. For this purpose, dexamethasone is administered at 0.25 to 0.5 mg/kg every six hours, with a maximum daily dose of 16 mg. The single dose should not exceed 8 mg.

Approach to Traumatic IIPS

• New guidelines do not recommend the use of prophylactic phenytoin or valproate to prevent late post-traumatic seizures (PTN). For early PTN prophylaxis, however, phenytoin is recommended to reduce the incidence of early PTN (within 7 days of injury) when the overall benefit is considered to outweigh treatment-related complications (evidence level IIA).[6]

• Two factors determine adequate blood flow to the brain (i.e., cerebral tissue perfusion). The first is CBF, and the second is ICP. Some researchers argue that normalizing CBF is more important, and that ICP should be considered secondary.[26] However, it has been demonstrated that the pathophysiology underlying the development of brain injury cannot be explained by CPP alone; increased ICP is also associated with a poor prognosis. Therefore, while striving to maintain adequate CPP, clinicians must also control ICP. This is only possible through ICP monitoring.

• Providing appropriate sedation to prevent agitation may contribute to controlling ICP. Benzodiazepines are generally preferred for sedation. Considering the use of appropriate analgesia and sedation during routine intensive care monitoring, it is recommended to avoid bolus administration of midazolam and/or fentanyl during ICP crises due to the risks of cerebral hypoperfusion (evidence level III).[6] Alternatively, intervention with pentobarbital may be necessary in such cases.

Traditionally, ketamine has been considered contraindicated in patients with high ICP; there is concern that it may increase CBF and further elevate ICP.[6] The use of etomidate for ICP control is largely of historical significance, as other sedatives and analgesics that do not suppress adrenal function are now available.[6]

• Decompressive craniectomy: The benefit of this procedure for patients with severe traumatic brain injury is controversial.[6] Potential complications of decompressive craniectomy, such as hygroma, hydrocephalus, and aseptic bone resorption, should be considered.

• The use of steroids to reduce trauma-induced ICP elevation is not recommended (evidence level I).[6] In cases of severe head trauma, high-dose methylprednisolone has been associated with increased mortality and is contraindicated.[27]

Refractory IIPS Cases

• A 20% saline bolus may be administered for refractory ICH. The recommended dose is 0.5 mL/kg, with a maximum of 30 mL (evidence level III).[6]

• CSF drainage: In cases of uncontrolled intracranial hypertension, a neurosurgeon may place an intraventricular shunt for CSF drainage and ICP monitoring. Permanent ventricular shunts are another option.

• Decompressive craniectomy: The removal of a portion of the skull to reduce ICP. Decompressive craniectomy is recommended for treatment of medically resistant neurological deterioration, risk of herniation, or uncontrolled intracranial hypertension (evidence level III).[6]

Footnotes

This protocol has been prepared to provide pediatricians with general information on "increased intracranial pressure syndrome" and is not intended to replace the physician's professional judgment. It should not be used alone for patient diagnosis, treatment, or follow-up.

Authorship Contributions

Surgical and Medical Practices: Ç.K., Concept: Ç.K., Design: Ç.K., A.Ç., R.Y., Data Collection or Processing: Ç.K., Analysis or Interpretation: Ç.K., A.Ç., F.İ.G., F.K., M.U.Y., P.Y.Ö., R.Y., U.E.S., Literature Search: Ç.K., A.Ç., F.İ.G., F.K., M.U.Y., P.Y.Ö., R.Y., U.E.S., Writing: Ç.K., A.Ç., F.İ.G., F.K., M.U.Y., P.Y.Ö., R.Y., U.E.S.

Conflict of Interest: No conflict of interest was declared by the authors. Some of the authors of this article (A.Ç.), (M.U.Y.), (U.E.S.) are members of the Editorial Board of this journal, and some (Ç.K.), (F.İ.G.), (F.K.), (P.Y.Ö.), (R.Y.) are reviewers of this journal. These authors had no role in the peer review process or the editorial decision of the article. The peer review process and the editorial decision were conducted independently by another editor.

Financial Disclosure: The authors declared that this study received no financial support.

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DOI: 10.4274/cayd.galenos.2026.20591
J Pediatr Emerg Intensive Care Med 2026;13(2):139-41

Pediatric Extracorporeal Membrane Oxygenation Practices in Türkiye: Problems and Solutions

Türkiye'de Pediyatrik Ekstrakorporeal Membran Oksijenasyon Uygulamaları: Sorunlar ve Çözümler

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Dear Editor,

Access to extracorporeal membrane oxygenation (ECMO) is a critical issue even in developed countries. For example, there are no reports on ECMO accessibility in Türkiye, whereas in the USA one-third of the population does not have access to ECMO.[1] Using aeromedical services to transfer patients to ECMO centers is the most suitable means of addressing this problem.[1]

Despite its use of high technology, the safety and quality of ECMO primarily depend on staff education and human factors. During extracorporeal life support (ECLS), procedural stress and workload increase, but dependence on team performance decreases over time. It is also a complex process. In ECLS applications, successful decision-making is possible in systems with effective communication and individual responsibility. Thus, a competent ECLS team leader and ECMO simulation training are crucial.[2] During ECMO runs, personnel should use checklists to identify errors in the process.

In a German study, a perfusionist-free method was evaluated at a university hospital. A wet-in-primed ECMO circuit was set up for cannulation and checked by the perfusionist. The method was found to be feasible and safe.[3] ECMO centers in our country could consider implementing this method in settings with low availability of perfusionists.

There are many difficulties in establishing ECMO programs in developing countries. These include a lack of resources, financial restrictions, limited infrastructure, equipment shortages, a lack of trained personnel, obligations to achieve sufficient case volumes, and the absence of an appropriate, standardized ECMO protocol at medical centers.[4]

As part of the Turkish pediatric ECMO study group, Ekinci et al.[5] conducted a survey of ECMO presence and capabilities in pediatric intensive care units across Türkiye and of the units' directors. According to unpublished data from the Turkish pediatric ECMO study group, half of the pediatric intensive care units are able to perform ECMO, while the other half transfer ECMO patients to hospitals with an ECMO center. The most widespread problem was the lack of surgeons or expertise in pediatric patient cannulation. Other common problems, in sequence, are the lack of trained staff and of ECMO equipment. 80% of the ECMO centers performed ECMO in the last five years, and 80% of these centers performed fewer than five ECMO treatments a year.[5] Based on these data, governors and policymakers need to resolve the problems.

We could offer solutions to address problems in pediatric ECMO in Türkiye. First, local ECMO centers should be restructured by the National Health Services based on the child population in each region. Second, pediatric intensivists

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Received/Geliş Tarihi: 03.03.2026 **Accepted/Kabul Tarihi:** 17.06.2026 **Publication Date/Yayınlanma Tarihi:** 07.08.2026
Cite this article as: Özcan S, Ekinci F, Kendirli T. Pediatric extracorporeal membrane oxygenation practices in Türkiye: problems and solutions. J Pediatr Emerg Intensive Care Med. 2026;13(2):139-41

and cardiac surgeons should be trained by a board of cardiovascular surgeons in pediatric ECMO and cannulation procedures. Additionally, pediatric intensive care nurses and perfusionists should receive regular training from healthcare providers. ECMO centers should have sufficient devices and cannulas. If the center lacks sufficient ECMO devices or the patient is not suitable for transfer, cardiac surgeons should perform cannulation and connect the patient to a bypass device. The patient can then be stabilized directly or by a pediatric intensivist via telemedicine. Once stabilized, the patient can be transferred to an ECMO center. Rather than attempting to transport critically ill pediatric patients to a specialized center without ECMO support, it is safer for a specialist team to deploy to the patient's location, initiate ECMO promptly, and transport the patient while the patient remains supported by ECMO.[6] Currently, there are no specified ECMO transport aircraft, ground ambulance vehicles, or ECMO teams in Türkiye. This situation causes transportation-related problems. Sometimes, ECMO center members go to the patient's hospital, set up the circuit, and transport the patient on ECMO. The first Turkish pediatric ECMO transport series was reported in 2022.[7] Six patients were transferred to a referral center by air transport. No complications were reported by the authors.[7] Another issue in Türkiye is that double-lumen cannulas for venovenous ECMO are not available for infants. Instead, venoarterial ECMO is used for pediatric acute respiratory distress syndrome and is associated with increased complications and morbidity in affected infants. The Second Pediatric Acute Lung Injury Consensus Conference of the pediatric acute lung injury and sepsis investigators network suggests the use of veno-venous ECMO over veno-arterial ECMO in patients with pediatric acute respiratory distress syndrome who have adequate cardiac function.[8] Some pediatric cardiac hospitals have treated children with congenital heart disease for years. The doctors in pediatric cardiac hospitals have also performed ECMO for years, and they should be included in the pediatric ECMO program for children with heart diseases.[9]

We established the pediatric ECMO study group within the Turkish Society of Pediatric Emergency and Intensive Care Medicine in 2021. Members of the pediatric ECMO study group are included in this study. This Turkish pediatric ECMO study group evaluates problems, challenges, and solutions related to performing pediatric ECMO. We conduct two pediatric ECMO courses for pediatric intensivists and provide training for fellows, including lectures on pediatric ECMO practices. Our educational program can contribute to a pediatric ECMO program in Türkiye. In addition, our study group has published pediatric ECMO guidelines, which are available on the Turkish Society of Pediatric Emergency and Intensive Care Medicine website.[10] The Turkish pediatric ECMO study group has conducted epidemiological studies, which have contributed to national and global ECMO data.

A pediatric ECMO program in Türkiye should provide solutions because these problems cannot be completely identified and resolved by pediatric intensive care specialists. The Ministry of Health should form a national ECMO committee and establish a program to detect problems and find solutions not only for pediatric patients but also for neonates and adults. The ECMO program should include established regional ECMO centers; trained doctors (especially intensivists), surgeons, nurses, and perfusionists; and mobile ECMO teams to serve remote regions.

Keywords: Children, developing countries, extracorporeal membrane oxygenation

Anahtar Kelimeler: Çocuk, gelişmekte olan ülkeler, ekstrakorporeal membran oksijenasyonu

Footnotes

Authorship Contributions

Surgical and Medical Practices: S.Ö., T.K., Concept: F.E., T.K., Design: S.Ö., T.K., Data Collection or Processing: S.Ö., F.E., Analysis or Interpretation: S.Ö., F.E., T.K., Literature Search: S.Ö., F.E., T.K., Writing: S.Ö., T.K.

Conflict of Interest: No conflict of interest was declared by the authors.

One of the authors of this article (T.K.) is member of the Editorial Board of this journal, and two authors (S.Ö.), (F.E.) are reviewers for the journal. These authors had no role in the peer review process or the editorial decision of the article. The peer review process and the editorial decision were conducted independently by another editor.

Financial Disclosure: The authors declared that this study received no financial support.

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