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Research Article

Etiology, clinical findings, and mortality in pediatric trauma: a retrospective analysis from Çanakkale

Pediatrik travmada etyoloji, klinik bulgular ve mortalite: Çanakkale'den retrospektif bir analiz

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Abstract

Introduction: Trauma remains one of the leading causes of death in childhood and adolescence, even in developed countries. Reducing trauma-related mortality in children continues to be a major public health concern. Physiological, anatomical, and developmental differences between children and adults influence both trauma mechanisms and treatment processes. Notably, head trauma is a primary cause of pediatric intensive care unit (PICU) admissions. This study aimed to evaluate the clinical characteristics and survival outcomes of children requiring intensive care following trauma.

Methods: In this retrospective study, 90 pediatric patients admitted to a PICU due to trauma between January 2019 and December 2023 were evaluated. Data were collected from electronic medical records, including demographic characteristics, mode of admission, trauma etiology, vital signs, laboratory values, imaging results, types of respiratory support, treatments administered, scoring systems (GCS, PEWS, PRISM III, PELOD, ISS, PTS, AIS), and mortality outcomes. The association between biomarkers—such as lactate, pH, standard base excess (SBE), and INR—and mortality was analyzed using ROC curve analysis.

Results: Of the patients, 7,.8% were male, with a mean age of 104,96±68,08 months. The most common trauma mechanism was falling from height (28,9%), followed by motorcycle accidents (16,7%) and drowning (16,7%). Head and neck injuries were present in 65,6% of cases, while extremity and skin involvement was observed in 75,6%. Invasive mechanical ventilation was required in 31,1% of the patients. The mean GCS was 11,7±0,44, and the mean ISS was 25,41±2,14. Seven patients (7,8%) died. The highest mortality rates were observed in cases of firearm injuries (100%), hanging/asphyxia (25%), and drowning (13,3%). Significant differences were found in pH, SBE, lactate, INR, and creatinine levels between survivors and non-survivors (all $p<0.05$). According to ROC analysis, lactate was the strongest single predictor of mortality (AUC: 0.848); however, when all four biomarkers were combined, the AUC reached 1.000. GCS, PRISM III, PELOD, and ISS scores were significantly correlated with mortality ($p<0.001$).

Conclusion: This study demonstrates that early risk assessment based on trauma mechanisms, clinical scores, and laboratory parameters can effectively predict mortality in pediatric trauma patients. The combined use of biomarkers such as lactate, pH, SBE, and INR provides a stronger predictive value than individual parameters alone. The high rates of head and neck injuries and the need for mechanical ventilation highlight the importance of early intervention. The frequent occurrence of trauma mechanisms such as motorcycle accidents and drowning among adolescent males underscores the need to develop targeted public health prevention strategies for this population.

Keywords: Child, Critical Care, Accidents, Injury Severity Score, Motorcycles

Öz

Giriş: Travma, gelişmiş ülkelerde bile çocukluk ve ergenlikte önde gelen ölüm nedenlerinden biri olmaya devam etmektedir. Çocuklarda travmayla ilişkili ölüm oranını azaltmak önemli bir halk sağlığı endişesi olmaya devam etmektedir. Çocuklar ve yetişkinler arasındaki fizyolojik, anatomik ve gelişimsel farklılıklar hem travma mekanizmalarını hem de tedavi süreçlerini etkiler. Özellikle, kafa travması çocuk yoğun bakım ünitesi(ÇYBÜ) yatışlarının birincil nedenidir. Bu çalışma, travmadan sonra yoğun bakım gerektiren çocukların klinik özelliklerini ve sağkalım sonuçlarını değerlendirmeyi amaçlamaktadır.

Yöntem: Bu retrospektif çalışmada, Ocak 2019 ile Aralık 2023 arasında travma nedeniyle ÇYBÜ'yeyatırılan 90 pediatrik hasta değerlendirildi. Veriler, demografik özellikler, yatış şekli, travma etiyolojisi, hayati bulgular, laboratuvar değerleri, görüntüleme sonuçları, solunum desteği türleri, uygulanan tedaviler, puanlama sistemleri (GKS, PEWS, PRISM III, PELOD, ISS, PTS, AIS) ve ölüm sonuçları dahil olmak üzere elektronik tıbbi kayıtlardan toplandı. Biyobelirteçler (laktat, pH, SBE ve INR gibi) ile mortalite arasındaki ilişki ROC eğrisi analizi kullanılarak analiz edildi.

Sonuçlar: Hastaların %7,8'i erkekti ve ortalama yaşları 104,96±68,08 ay idi. En sık görülen travma mekanizması yüksekten düşme (%28,9) idi, bunu motosiklet kazaları (%16,7) ve boğulma (%16,7) takip etti. Baş ve boyun yaralanmaları vakaların %65,6'sında mevcutken, ekstremite ve cilt tutulumu %75,6'sında gözlendi. Hastaların %31,1'inde invaziv mekanik ventilasyon gerekli oldu. Ortalama GKS 11,7±0,44 ve ortalama ISS 25,41±2,14 idi. Yedi hasta (%7,8) ex oldu. En yüksek mortalite oranları ateşli silah yaralanmaları (%100), asılma/asfiksi (%25) ve boğulma (%13,3) vakalarında gözlendi. pH, SBE, laktat, INR ve kreatinin düzeylerinde sağ kalanlar ve sağ kalmayanlar arasında önemli farklılıklar bulundu $p<0,05$). ROC analizine göre, laktat mortalitenin en güçlü tek öngörücüsüydü (AUC: 0,848); ancak, dört biyobelirteç birleştirildiğinde, AUC 1,000'e ulaştı. GKS, PRISM III, PELOD ve ISS skorları mortalite ile önemli ölçüde ilişkiliydi ($p<0,001$).

Sonuç: Bu çalışma, travma mekanizmalarına, klinik skorlara ve laboratuvar parametrelerine dayalı erken risk değerlendirmesinin pediatrik travma hastalarında mortaliteyi etkili bir şekilde öngörebileceğini göstermektedir. Laktat, pH, SBE ve INR gibi biyobelirteçlerin birlikte kullanımı, tek başına bireysel parametrelerden daha güçlü bir öngörü değeri sağlar. Baş-boyun yaralanmalarının ve mekanik ventilasyon gereksiniminin yüksekliği, erken müdahalenin önemini vurgulamaktadır. Özellikle motosiklet kazaları ve suda boğulma gibi mekanizmaların adölesan erkeklerde sık görülmesi, bu gruba yönelik koruyucu halk sağlığı stratejilerinin geliştirilmesi gerekliliğini ortaya koymaktadır.

Anahtar Sözcükler: Çocuk, Kritik Bakım, Kazalar, Yaralanma Şiddeti Puanı, Motosikletler

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Key Points

1. Head-neck injuries in pediatric trauma patients are significantly related to the need for mechanical ventilation.
2. Scoring systems such as PRISM III, PELOD and GCS have high predictive value in predicting mortality.
3. Lactate, pH, SBE and INR levels are significantly related to mortality; combined use of these four parameters improves prognostic accuracy (AUC: 1,000).
4. Motorcycle accidents are common in adolescent men and are at the forefront of trauma-related deaths.
5. The frequency of drowning cases increases due to regional tourism and coastal characteristics and carries a high risk of mortality.

Introduction

Trauma continues to be among the most common causes of death in childhood and adolescence, even in developed countries. Although significant advances have been made in preventive measures and post-traumatic care processes, reducing trauma-related mortality in children still exists as a major public health problem [1-4]. In recent years, it has been reported that changes in children's daily life habits, especially behavioral shifts, such as decreased physical activity and decreased uncontrolled outdoor play, reshaped the mechanisms of trauma [5-6]. This situation reveals that existing diagnosis and treatment approaches should be re-evaluated according to current trauma patterns. There are many physiological, anatomical and developmental differences between children and adults, and these differences cause the separation of trauma mechanisms, injury types and treatment processes [7-8]. Head injuries are among the main causes of the need for intensive care in childhood and have been shown to have a significant association between low Glasgow Coma Scale (GCS) scores and mortality [8-9]. Studies conducted in developed countries have shown that effective management of post-traumatic intensive care and rehabilitation processes reduces mortality and shortens hospital stay [10]. However, in developing countries where there are a limited number of child trauma centers, it can be challenging to achieve similar results [11]. When the distribution of trauma-related deaths is examined; deaths at the time of the event are observed at the highest rate, and early deaths usually develop due to hypovolemia, hypoxia and severe head trauma. In the late period, complications such as SIRS, sepsis, multiple organ failure and Acute Respiratory Disstres Syndrome come to the fore [8]. In mechanism-based evaluations, differences are seen according to age groups; falls are observed more frequently in young children, while traffic accidents and high-energy traumas come to the fore in adolescents [12-13]. In this context, the evaluation of the demographic characteristics, clinical parameters, trauma mechanisms and results of the cases admitted to the Pediatric Intensive Care Unit (PICU) due to trauma is of great importance in terms of understanding the regional trauma burden, resource planning and developing strategies for improving patient outcomes. This study aims to reveal the clinical characteristics and survival results of children with post-traumatic intensive care needs.

Methods

In the study, the data of a total of 771 patients who applied to PICU between January 2019 and December 2023 were examined retrospectively. The files of 110 patients who applied due to trauma were evaluated with data obtained from the hospital's electronic system. Patients exposed to trauma are classified according to trauma mechanisms as follows: motor vehicle accidents (occupant), motor vehicle accidents (pedestrian), motorcycle accidents, falls from height, same-level falls/collisions, penetrating/stabbing injuries, firearm injuries, drowning, hanging/asphyxia and other types of trauma. A patient who has been hospitalized for less than 24 hours in PICU, 15 patients exposed to environmental trauma (carbon monoxide poisoning, snake bite, etc.) and 4 patients with missing data were not included in the study. As a result, the study sample was limited to 90 patients. The data used in the study are based on the patient evaluation form created with the information obtained from the hospital's electronic system. Among the data included in this form; demographic information of patients, year and season of admission to hospital, settlements, type of intensive care application, duration of stay in intensive care, trauma etiologies, injured organ systems, vital signs determined by age, laboratory and radiological examination results, respiratory support requirements, clinical status, treatments they receive, consultations, necessary types of operations and hospital-related infections. Blood glucose values were determined as <60 mg/dl for hypoglycemia and >200 mg/dl for hyperglycemia. The worst values and findings in the first 24 hours of intensive care admissions of patients were recorded by calculating the scores of PEWS, AVPU, GCS, PRISM III and PELOD. PTS, AIS and ISS scores were calculated according to the physical examination, radiological imaging, respiratory and circulatory support requirements at the time of application.

Ethical Approval

This study was approved by the Non-Interventional Research Ethics Committee of Çanakkale Onsekiz Mart University Faculty of Medicine with the decision dated 13.12.2023 and numbered 2023/16-03.

Statistical Analysis

Appropriate statistical package programs were used for the statistical analysis of the data obtained in the study. Descriptive statistics were presented as mean ± standard deviation, median (minimum–maximum) for continuous variables; number and percentage (%) for categorical variables. The distribution properties of continuous variables were evaluated by graphical methods (histogram, Q-Q plot) and the Shapiro-Wilk test. The Mann-Whitney U test was used in the comparison of continuous variables that did not match the normal distribution, and the Chi-Square (χ^2) test was used in the comparison of categorical variables. The level of statistical significance was considered $p < 0.05$. In the study, the relationship of clinical scoring systems such as GCS, PRISM-III, PELOD and ISS with survival status was evaluated by the Mann-Whitney U test. In addition, ROC (Receiver Operating Characteristic) analysis was performed to determine the distinctive strength of clinically important laboratory parameters such as Lactate, pH, Base excess and INR on survival. In the ROC analysis, the AUC (Area Under the Curve) value was presented with 95% Confidence Interval (CI), sensitivity and specificity values. The predictive strength of mortality was analyzed by determining the optimal threshold value (cut-off) for the parameters. Variables with AUC > 0.500 were considered to have prognostic values. While creating multivariate estimation models, the effects on AUC were presented comparatively by combining the laboratory parameters evaluated one by one (e.g. Lactate + pH + base excess + INR combination). Graphs of ROC analysis were included in the study. Incomplete observations in the data set were excluded from the analysis. Multiple test corrections were not made in the study. Although no effect size measurements were made, the AUC and sensitivity/specificity ratios in the ROC analysis were interpreted in terms of the clinical significance of the results.

Results

In this study, a total of 90 patients who were admitted to PICU due to trauma were retrospectively evaluated. Of these patients, 77.8% were male (n = 70) and 22.2% were female (n = 20). The mean age of the included patients was calculated as 104.96 ± 68.08 months, indicating a wide age distribution (Figure 1).

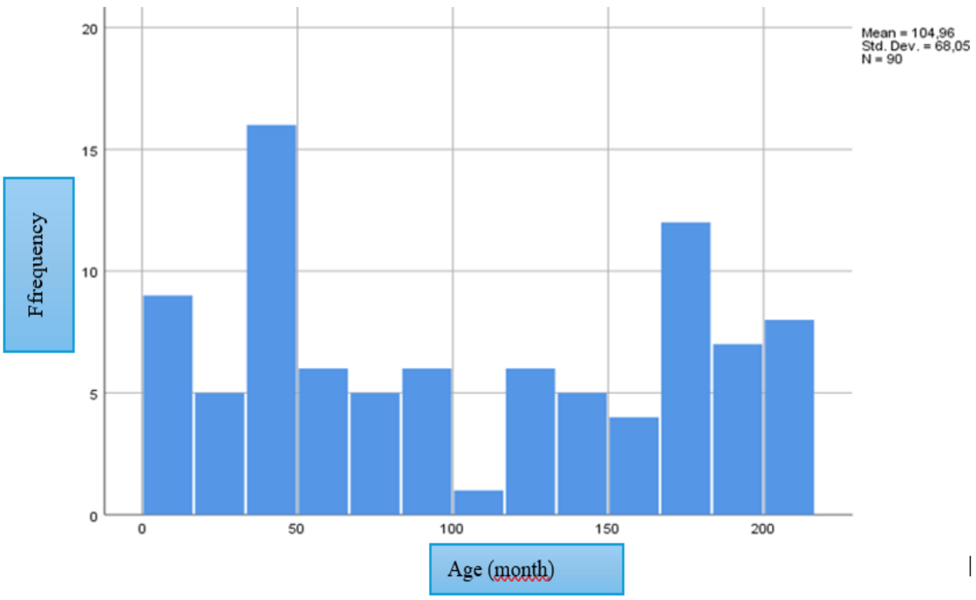

Figure 1. Distribution of patients admitted to due to trauma according to age groups.

When the mechanisms of trauma were analyzed, the most common cause was falling from height, observed in 28.9% of the patients (n = 26). This was followed by motorcycle accidents (16.7%), drowning (16.7%), and pedestrian motor vehicle accidents (15.6%). Gunshot wounds and penetrating/stabbing injuries were the least common causes of trauma, each accounting for 1.1% of cases (Table 1).

Table 1. Classification of pediatric trauma patients according to trauma mechanisms (n=90)

Trauma Mechanism	**n (%)**
Falls from height	26 (28.9)
Motorcycle accidents	15 (16.7)
Drowning	15 (16.7)
Intra-vehicle Traffic Accident (IVTA)	14 (15.6)
Extra-vehicle Traffic Accident (EVTA)	8 (8.9)
Same-level falls/collisions	4 (4.4)
Hanging/asphyxia	4 (4.4)
Other types of trauma	2 (2.2)
Penetrating/stabbing injuries	1 (1.1)
Firearm injuries	1 (1.1)

N: Number of patients, %: Indicates the percentile rate in the relevant group

In the ROC analysis, the Area Under the Curve (AUC) was calculated as 0.848 for lactate, 0.731 for pH, 0.807 for SBE, and a specific AUC value was also obtained for INR (Figure 2). The combined model incorporating all these parameters yielded an AUC of 1.000, indicating an exceptionally high predictive accuracy for mortality.

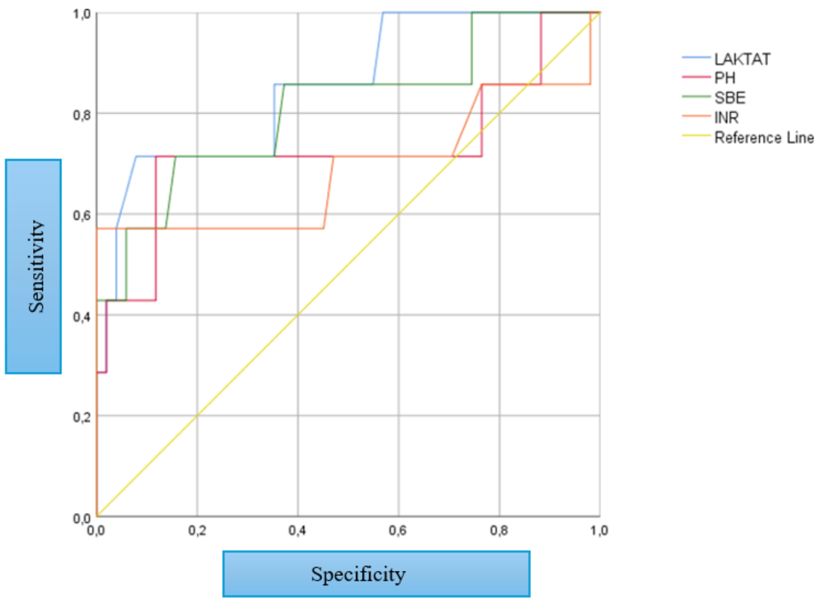

Figure 2. ROC curves and predictive performance for mortality based on Lactate, pH, SBE, and INR variables.

The head and neck region was affected in 65.6% of the patients. Thoracic injuries were observed in 53.3%, while abdominal injuries were present in 24.5% of the cases. Extremity and skin injuries were reported in 75.6% of the patients, the majority of which were soft tissue injuries. Fractures, multiple fractures, and their combinations were observed less frequently (Table 2).

Table 2. Patient distribution according to anatomical system involvement related to trauma (n=90)

Trauma Region	Status	n (%)
Head/Neck Injury	Present	59 (65.6)
	Absent	31 (34.4)
Thoracic Injury	Present	48 (53.3)
	Absent	42 (46.7)
Abdominal Injury	Present	22 (24.5)
	Absent	68 (75.5)
Extremity and Skin Injuries	Soft Tissue Injury	68 (75.6)
	Fracture	8 (8.9)
	Multiple Fractures	1 (1.1)
	Soft Tissue Injury + Fracture	5 (5.6)
	Soft Tissue Injury + Multiple Fractures	8 (8.9)

n: number of patients; %: percentage within the relevant group

Among the patients, 44.4% were managed with room air, while 31.1% required invasive mechanical ventilation. Non-invasive respiratory support was administered to 3.3% of patients. The remaining patients received oxygen therapy via nasal cannula/simple face mask (12.2%) or non-rebreather mask (8.9%) (Table 3).

Table 3. Patient distribution according to respiratory support requirement after trauma (n=90)

Type of Respiratory Support	n (%)
Room Air (No Respiratory Support)	40 (44.4)
Nasal Cannula / Simple Mask	11 (12.2)
Reservoir Mask	8 (8.9)
Non-Invasive Mechanical Ventilation (NIV)	3 (3.3)
Invasive Mechanical Ventilation (IMV)	28 (31.1)

n: number of patients; %: percentage within the respective group

The most frequently administered treatment was sedation and analgesia (71.1%), followed by antibiotic prophylaxis (74.4%) and gastrointestinal system (GIS) prophylaxis (54.4%). Intracranial hypertension (ICH) treatment was provided to 30.0% of patients. Similarly, 30.0% received hyperosmolar therapy, including hypertonic saline (23.3%) and mannitol (6.7%). Blood product transfusions and inotropic support were applied in 18.9% and 13.3% of cases, respectively (Table 4).

Table 4. Patient distribution according to medical treatment modalities applied in pediatric intensive care unit (n=90)

Medical Treatments		n (%)
Shock Therapy		17 (%18.9)
Inotropic Support		12 (%13.3)
Blood Product Support		17 (%18.9)
Increased Intracranial Pressure (ICP) Treatment		27 (%30.0)
Hyperosmolar Therapy	Hypertonic Saline	21 (%23.3)
	Mannitol	6 (%6.7)
Sedation/Analgesia		64 (%71.1)
Muscle Relaxants		12 (%13.3)
Gastrointestinal (GI) Prophylaxis		49 (%54.4)
Antibiotic Prophylaxis		67 (%74.4)
Convulsion Prophylaxis		27 (%30)

n: number of patients; %: percentage within the relevant group

The mean scores for clinical assessment tools were as follows: GCS 11.70 ± 0.44, Pediatric Early Warning Score (PEWS) 3.09 ± 0.31, Pediatric Trauma Score (PTS) 7.34 ± 0.34, PRISM III 5.70 ± 0.96, and PELOD 4.80 ± 1.08 (Table 5).

Table 5. Mean, standard deviation, and median distributions of GCS, PEWS, PTS, PRISM III, and PELOD scores in pediatric intensive care patients admitted due to trauma

Scoring System	Mean ± Standard Deviation	Median (Min-Max)
GCS :	11,7 ± 0,44	14 (3-15)
PEWS :	3,09 ± 0,31	2 (0-10)
PTS :	7,34 ± 0,34	8 (0-12)
PRISM III :	5,7 ± 0,96	2 (0-47)
PELOD :	4,8 ± 1,08	0 (0-60)

GCS: Glasgow Coma Scale. **PEWS:** Pediatric Early Warning Score. **PTS:** Pediatric Trauma Score. **PRISM III:** Pediatric Risk of Mortality Score, Version 3. **PELOD:** Pediatric Logistic Organ Dysfunction Score

The highest mean Abbreviated Injury Scale (AIS) scores were recorded for the head-neck (2.33 ± 0.20) and thoracic (1.73 ± 0.17) regions. The average Injury Severity Score (ISS) was 25.41 ± 2.14 (Table 6).

Table 6. Distribution of anatomical injury scores (AIS) according to body regions and total injury severity score (ISS)

Scoring System	Mean±Standard Deviation	Median(MinMax)
AIS 1:(Head-Neck)	2.33 ± 0.20	3 (0-5)
AIS 2: (Face)	1.37 ± 0.15	1 (0-5)
AIS 3:(Thorax)	1.73 ± 0.17	2 (0-5)
AIS 4:(Abdomen)	0.73 ± 0.14	0 (0-4)
AIS 5:(Extremity)	1.19 ± 0.09	1 (0-4)
AIS 6:(Skin)	1.39 ± 0.11	1 (0-4)

Values Presented as Mean ± Standard Deviation and Median (Min–Max). AIS: Abbreviated Injury Scale. ISS: Injury Severity Score

Hospital and PICU length of stay were significantly longer in patients who received blood product transfusions or ICH-directed therapy ($p < 0.001$). However, no statistically significant difference in length of stay was observed in those receiving inotropic support (Table 7).

Table 7. Comparison of hospital and ıntensive care unit length of stay between patients receiving and not receiving blood product transfusion, ınotropic support, and ıntracranial pressure (ICP) therapy

Groups	Hospital Length of Stay (days)	PICU Length of Stay (days)	p-value
Patients Receiving Blood Products (n=17)	22.94 ± 6.98	14.00 ± 3.61	< 0.001
Patients Not Receiving Blood Products	7.15 ± 1.31	4.30 ± 0.80	< 0.001
Patients Receiving Inotropic Support(n=12)	7.58 ± 1.63	6.33 ± 1.62	0.800
Patients Not Receiving Inotropic Support	10.5 ± 2.05	6.10 ± 1.14	0.130
Patients Receiving ICP Therapy(n=27)	21.44 ± 5.33	13.22 ± 2.93	< 0.001
Patients Not Receiving ICP Therapy	5.29 ± 0.46	3.10 ± 0.24	< 0.001

Data are presented as mean ± standard deviation. p-values were calculated using the independent samples t-test. ICP: Intracranial Pressure

Seven patients (7.8%) died. The highest mortality rates were observed in cases involving firearm injuries (100.0%), hanging/asphyxia (25.0%), and drowning (13.3%) (Table 8).

Table 8. Distribution of case numbers and their association with mortality according to trauma mechanismsexitus, refers to the number of patients who died during hospitalization.

Trauma Mechanism	Number of Cases (n)	Exitus (n)	Discharges (n)
Motorcycle Accident	15	2	13
Fall from Height	26	0	26
IVTA	8	0	8
EVTA	14	1	13
Drowning	15	2	13
Hanging/Asphyxia	4	1	3
Fall/Impact on the Same Level	4	0	4
Firearm Injury	1	1	0
Penetrating/ stabbing Instrument Injury	1	0	1
Other Traumas	2	0	2

IVTA: Intra-vehicle Traffic Accident. **EVTA**: Extra-vehicle Traffic Accident. **n:** Number of patients

Compared to survivors, non-survivors had significantly lower pH levels (7.160 ± 0.250 vs. 7.340 ± 0.950; $p = 0.001$), more negative base excess (SBE) values (−10.820 ± 8.480 vs. −2.180 ± 5.540; $p = 0.043$), higher lactate levels (8.120 ± 7.550 vs. 2.850 ± 1.850; $p < 0.001$), elevated INR (1.500 ± 0.450 vs. 1.130 ± 0.110; $p < 0.001$), and higher serum creatinine (1.100 ± 0.800 vs. 0.570 ± 0.220; $p = 0.002$) (Table 9).

Table 9. Statistical comparison of key laboratory parameters according to mortality status

Parameters	Exitus (n=7) Mean ± SD	Survivors (n=83) Mean ± SD	p-Value
pH	7.16 ± 0.25	7.34 ± 0.95	0.001
PCO2(mmHg)	46.22 ± 19.31	41.70 ± 9.6	0.30
SBE	-10.82 ± 8.48	-2.18 ± 5.54	0.043
Lactate (mmol/L)	8.12 ± 7.55	2.85 ± 1.85	<0.001
Hb(g/dL)	11.85 ± 3.74	11.69 ± 1.68	0.83
INR	1.50 ± 0.45	1.13 ± 0.11	<0.001
Creatinine	1.10 ± 0.80	0.57 ± 0.22	0.002

pH: Indicator of acid-base balance. **PCO_2:** Partial pressure of carbon dioxide. **SBE:** Standard Base Excess. **Hb:** Hemoglobin. **INR:** International Normalized Ratio

In terms of scoring systems, non-survivors had significantly lower GCS and PTS scores, whereas PEWS, PRISM III, and PELOD scores were significantly higher (p < 0.050 for all comparisons) (Table 10).

Table 10. Comparison of pediatric scoring systems according to mortality status

Scoring System	Exitus (n=7) Mean± SD	Survivors (n=83) Mean± Sd	p-value
GCS	3.43 ± 1.13	12.42 ± 3.55	0.003
PEWS	7.14 ± 1.06	2.66 ± 2.68	0.005
PTS	2.43 ± 2.60	7.76 ± 2.96	0.001
PRISM-III	29.29 ± 10.06	3.78 ± 5.67	0.03
PELOD	30.86 ± 14.86	2.69 ± 5.94	0.022

GCS: Glasgow Coma Scale. **PEWS:** Pediatric Early Warning Score. **PTS:** Pediatric Trauma Score. **PRISM III:** Pediatric Risk of Mortality Score Version 3. **PELOD:** Pediatric Logistic Organ Dysfunction Score

Cranial CT revealed soft tissue injuries in 45.6%, cranial fractures in 37.8%, and intracranial hemorrhage in 30.0% of patients. Diffuse axonal injury was detected in 6 patients (6.7%) on cranial MRI. Thoracic CT most commonly demonstrated pulmonary contusion/consolidation (42.2%). On abdominal CT and ultrasound, liver and splenic lacerations, hematomas, and bladder injuries were among the prominent findings (Table 11).

Table 11. Distribution of findings detected by ımaging modalities in pediatric patients following trauma

Imaging Modality	Findings	n (%)
Cranial CT	Cranial bone fractures	34 (37.8)
	Hemorrhage	27 (30.0)
	Contusion	13 (14.4)
	Edema	16 (17.8)
	Soft tissue injury	41 (45.6)
	Cervical vertebra fracture	2 (2.2)
Cranial MRI	Diffuse axonal injury	6 (6.7)
Thoracic CT	Pulmonary contusion/consolidation	38 (42.2)
	Pneumothorax	10 (11.1)
	Hemothorax	3 (3.3)
	Costa fracture	4 (4.4)
	Clavicle fracture	6 (6.7)
	Sternum fracture	1 (1.1)
	Thoracic vertebra fracture	5 (5.6)
Abdominal CT	Liver hematoma	3 (3.3)
	Liver laceration	5 (5.6)
	Spleen hematoma	2 (2.2)
	Spleen laceration	4 (4.4)
	Bladder hematoma	4 (4.4)
	Kidney laceration	1 (1.1)
	GIS injury	2 (2.2)
	Lumbar vertebra fracture	3 (3.3)
Abdominal USG	Liver hematoma	5 (5.6)
	Liver laceration	5 (5.6)
	Spleen hematoma	2 (2.2)
	Spleen laceration	5 (5.6)
	Bladder hematoma	3 (3.3)
	Kidney laceration	1 (1.1)
	GIS injury	3 (3.3)

n: Number of patients; %: Percentage within the respective group. **CT:** Computed Tomography. **MRI:** Magnetic Resonance Imaging. **GIS:** Gastrointestinal System

In ROC analysis, the AUC for lactate was 0.848 (p = 0.003), for pH 0.731 (p = 0.048), and for SBE 0.807 (p = 0.008). When the predictive power of lactate, pH, base excess (SBE), and INR for mortality was compared via ROC curves, lactate demonstrated the highest individual AUC value. In a combined model incorporating all these parameters, the AUC was found to be 1.000, indicating perfect discrimination for predicting mortality (Tables 12–13, Figure 2).

Table 12. Evaluation of the diagnostic performance of lactate, pH, SBE, and INR values in predicting mortality using ROC analysis

Parameters	AUC± Standart Error	%95 CI	Cut-off	p	Sensitivity (%)	Specificity (%)
Lactate	0.848±0.084	0.683-1.000	6.25	**0.003**	71.40	92.50
pH	0.731±0.137	0.462-0.999	7.22	**0.048**	71.40	89.50
SBE	0.807±0.105	0.602-1.000	-6.35	**0.008**	71.40	86.00
INR	0.704±0.143	0.424-0.984	-	0.075	-	-

pH: Indicator of acid-base balance. **SBE:** Standard Base Excess. **INR:** International Normalized Ratio. **CI:** Confidence Interval

Table 13. Comparison of the diagnostic accuracy of different laboratory parameter combinations for predicting mortality using area under the roc curve (auc) values

	AUC	95% CI
Lactate	0.848	0.683-1.000
Lactate + pH	0.849	0.680-1.000
Lactate + pH + SBE	0.876	0.737-1.000
Lactate + pH + SBE+INR	1.000	1.000-1.000

pH: Indicator of acid-base balance. **SBE:** Standard Base Excess. **INR:** International Normalized Ratio. **CI:** Confidence Interval

A statistically significant association was observed between mortality and GCS, PRISM III, PELOD, and ISS scores ($p < 0.001$ for all) (Table 14).

Table 14. Comparison of mean scores according to scoring systems in exitus and surviving pediatric trauma patients

Scoring System	Mean Score (Exitus)	Mean Score (Survivors)	p-value
GCS	3.43±1.13	12.42±3.55	**<0.001**
PRISM III	29.29±10.06	3.78±5.67	**<0.001**
PELOD	30.86±14.86	2.69±5.94	**<0.001**
ISS	46.86±18.65	23.31±12.47	**0.001**

GCS: Glasgow Coma Scale. **PRISM III:** Pediatric Risk of Mortality Score, Version 3. **PELOD**: Pediatric Logistic Organ Dysfunction Score
ISS: Injury Severity Score

Discussion

This study comprehensively analyzed the clinical, laboratory and scoring parameters associated with mortality in trauma patients admitted to the pediatric intensive care unit; The combined use of biomarkers such as lactate, pH, SBE and INR provided high diagnostic accuracy in predicting mortality. In addition, the significant relationships of factors such as trauma mechanisms, affected areas of the body and the need for invasive mechanical ventilation with mortality provide important clinical clues in determining the severity of the trauma. In our study, it was found that most patients exposed to trauma were boys (77.8 percent); this finding supports previous studies that indicated that trauma was more common in men [14]. There are different results in the literature regarding the average age of pediatric trauma patients. Previously, Densmore et al. [10] reported the mean age of pediatric trauma patients to be 12.2±6.2 years, while another study Voth et al. [15] found that the mean age of pediatric patients was 8 years.

Trauma mechanisms differ depending on the socioeconomic levels and cultural structures of countries. In the study, which included 10 years of data from Herbert et al. [16] from South Africa, it was reported that 39.8% of trauma cases were falls. Similarly, it has been shown in studies conducted in Türkiye that injuries due to falls are more common than other types of trauma [17]. In the studies of Varol et al. [18], the most frequent falls were detected as a trauma mechanism. The most common trauma mechanism in our cohort was falling from height (28.9%); this was followed by motorcycle accidents (16.7%) and suffocations (16.7%). These findings parallel the frequently reported trauma mechanisms in the studies on pediatric trauma. In the literature, falls from heights and traffic accidents are among the most common causes of childhood trauma. Rare trauma mechanisms include firearm injuries and piercing-cutting tool injuries, and such injuries are also rare in the literature in childhood trauma. In our cohort, a case due to firearm injury and a case due to piercing-cutting tool injury have been detected. The patient who applied for a firearm injury was missing, and the patient with a piercing-cutting instrument injury was discharged alive. In our study, the most common trauma mechanism observed was falls from height (28.9%), all of which were discharged safely. These results are in line with the current literature, which emphasizes that falling in childhood trauma is one of the main etiological factors [19]. In addition, motorcycle accidents in the adolescent period were observed with remarkable frequency in our study group. These accidents are thought to be related to the widespread use of motorcycles in our region. Motorcycle accidents, which are the second frequency among trauma mechanisms, ranked first among motor vehicle accidents. All patients who applied for a motorcycle accident were in the driver's position, their age ranged from 11 years, 5 months to 17 years old, and 93.3% of this group was male. These findings coincide with studies in the literature that noted the low compliance of adolescent men with risky driving behaviors and safety precautions [20]. In addition, blood ethanol level was measured in 12 patients who had a motorcycle accident, and a high value of 91.3 mg/dL) was detected in only one patient. While this suggests that alcohol use may be associated with trauma, it also suggests that alcohol use in adolescents may be shaped by regional differences and socio-cultural effects. Therefore, training programs suitable for age group characteristics and the introduction of legal restrictions on driving in areas where motorcycle use is common will be an important step in preventing traumatic morbidity and mortality. When evaluated in terms of mortality, motorcycle accidents and drowning cases shared the first place with a rate of 28.5%. The frequency of drowning can be explained by the fact that our region is a tourist and coastal region. Similarly, it is known that children and adolescents who remain unattended are at risk, especially during the increased swimming activities in the summer months. When mortality distribution according to trauma mechanisms was examined, the highest mortality rates were observed in motorcycle accidents, drowning, asphyxia and firearm injuries. These findings reveal that a significant part of traumatic deaths in children and adolescents are due to preventable causes. The data obtained emphasize that targeted preventive strategies should be developed against high-risk trauma mechanisms in the adolescent age group. Increasing traffic safety, swimming training, use of protective equipment and family/social awareness training will contribute to reducing the regional trauma burden. When the body regions affected by trauma were evaluated, the most injured anatomical region in pediatric cases was determined as the head and neck.

In our series, 65.6% of the patients had head-neck injuries. This finding is in line with the literature, which emphasizes that head trauma is the most common type of injury in childhood trauma and is one of the main causes of trauma-related mortality and morbidity. Mayer et al. [21] reported that head trauma was seen in 78.8% of childhood trauma. In addition, thoracic injury is 53.3% and abdominal injury is 24.5% in our series. Extremity and skin injuries were observed in 75.6% of the cases, soft tissue injuries were in the foreground in a significant part of this group, while fractures were observed at a lower rate (8.9%). This shows that most of the trauma cases are less severe but with clinically significant injuries. In the Anatomical Injury Score (AIS) evaluation, the highest average score was obtained in the head-neck region (2.33 ± 0.20). This shows that head trauma is also prominently prominent in terms of trauma severity. In other body regions, AIS means were 1.73 ± 0.17 for the thoracic, 1.37 ± 0.15 for the face, 1.39 ± 0.11 for the skin, 1.19 ± 0.09 for the extremities and 0.73 ± 0.14 for the abdominal, respectively. It has been observed that head trauma is more frequent and severe, especially in cases presenting with a fall from a height mechanism, and this is in parallel with the findings reported in previous studies, showing that high-energy traumas cause severe morbidity and mortality associated with head trauma. [9-13].

Mechanical ventilation support in pediatric patients after traumatic injury is a common requirement, especially in the critical clinical picture. In the literature, the relationship between the need and duration of a ventilator and mortality is strongly emphasized [22]. It has been reported that ventilation time and intensive care stay time increase significantly, especially in cases with erythrocyte suspension transfusion, and this situation also negatively affects mortality. In this study conducted by Hassan et al., it was shown that both the need for mechanical ventilation and the duration are significantly long in pediatric trauma patients who underwent erythrocyte transfusion. Similarly, the study conducted by Varol et al. [18] stated that all cases who lost their lives received erythrocyte suspension transfusion and the ventilation time in these patients was significantly longer than those who survived. Similarly, in our study, the rate of invasive mechanical ventilation application was determined as 31.1%, and the cases that did not require respiratory support were 44.4%. Patients who underwent noninvasive mechanical ventilation were 3.3%, those supported with nasal cannula or simple mask were 12.2% and those who used reservoir masks were 8.9%. These results show that the spectrum of respiratory support is broad in post-traumatic children and invasive ventilation is widely applied in severe injury situations. It was determined that the need for invasive mechanical ventilation was statistically significantly higher in patients with head-neck injury (p=0.011). This situation reflects the physiological and anatomical effects of head-neck trauma that can cause respiratory pathologies. In addition, in our study, both hospital stay (22.94 ± 6.98 days) and intensive care stay (14.00 ± 3.61 days) were significantly longer in patients undergoing erythrocyte transfusion (p < 0.001 for both comparisons). On the other hand, in patients who did not receive blood products, these periods were determined as 7.15 ± 1.31 days and 4.30 ± 0.80 days, respectively. Prolonged hospitalization times in patients who underwent blood product transfusion suggest that the cases were clinically more severe and the prognosis was worse. Similarly, both hospitals (21.44 ± 5.33 days) and intensive care stay periods (13.22 ± 2.93 days) were significantly longer in patients treated with KIBA (p < 0.001 for both comparisons). This supports that invasive support treatments are often applied to cases with more severe trauma and are closely related to prognosis. Our study reveals that the need for invasive mechanical ventilation, erythrocyte transfusion and KIBA treatment can be considered as determinants of clinical severity and poor prognosis in traumatic pediatric patients. These parameters should be considered in terms of early risk classification in pediatric trauma management.

Medical treatments applied in pediatric patients require intensive care treatment due to traumatic injury vary depending on the severity of the disease and accompanying complications. In our study, the fact that 71.1% of the patients underwent sedation and analgesia shows that effective control of trauma-related pain and anxiety in children is a priority in clinical management. Sedation and analgesia should be evaluated as a critical component in terms of ensuring hemodynamic stability in intensive care, tolerating invasive interventions and increasing mechanical ventilation compliance. Among medical interventions, the most performed were sedation/analgesia (71.1%), antibiotic prophylaxis (74.4%) and gastrointestinal tract prophylaxis (54.4%). These findings reveal that these three approaches are widely preferred in the prevention of early complications in pediatric intensive care practices. It was determined that the hospital (21.44 ± 5.33 days) and intensive care (13.22 ± 2.93 days) hospital stay in patients who underwent post-traumatic KIBA treatment were significantly longer than in patients who did not receive this treatment (p < 0.001 for both comparisons). Since KIBA treatment is applied to patients at high risk of morbidity, prolonged hospitalization reflects the clinical severity of these cases. Similarly, hospital (22.94 ± 6.98 days) and intensive care (14.00 ± 3.61 days) hospital stay times increased significantly in cases with blood product transfusion (p < 0.001). This suggests that blood transfusion is often associated with severe hemorrhagic traumas or serious clinical pictures such as hemodynamic instability. On the other hand, in our study, it was observed that the stay periods of hospital (7.58 ± 1.63 days) and intensive care (6.33 ± 1.62 days) in patients who received inotrope support were not significantly different from those who did not receive inotropic support (p > 0.05). This result reveals that although the use of inotrope is necessary in critical cases, it is not an adequate indicator in determining mortality or hospitalization time alone. Hyperosmolar therapy has been used to manage the increase in intracranial pressure, which is secondary to head trauma, and hypertonic saline was preferred by 23.3% and mannitol was preferred by 6.7%. In addition, convulsion prophylaxis was applied at a rate of 30% and played a role in the prevention of neurological complications that may develop secondary to trauma. In our study, the medical treatment strategies applied in pediatric trauma patients differ according to the severity of the trauma and the affected systems; In addition to standard applications such as sedation/analgesia, antibiotics and GIS prophylaxis, it is seen that intensive interventions such as transfusion and KIBA treatment are decisive for the clinical course. Prolongation of ventilation time and transfusion requirement are parameters that suggest worsening of prognosis, and multidisciplinary approach and early intervention in these patients play a key role in the healing process.

Various scoring systems to predict mortality in patients admitted to the PICU due to traumatic injuries play an important role in clinical decision-making. In our study, according to the general evaluation of the patient cohort, PRISM III (mean: 5.7 ± 0.96; median: 2; min–max: 0–47) and PELOD (mean: 4.8 ± 1.08; median: 0; min–max: 0–60) scores indicated the clinical picture of moderate intensity. These values were found to be consistent with the scores reported in the pediatric trauma population in the literature [18] [23]. When the relationship between mortality and scoring systems was evaluated, it was determined that all systems showed significant differences. The mean PRISM III score of 7 patients resulting in exitus was 29.29 ± 10.06, while this score was 3.78 ± 5.67 in the 83 surviving patients (p < 0.001). Similarly, the PELOD score was found to be 30.86 ± 14.86 in patients with ex and 2.69 ± 5.94 in survivors (p < 0.001). These data emphasize the decisive effect of organ dysfunction on mortality. ISS, another indicator of trauma severity, was calculated as 46.86 ± 18.65 in the exitus group and doubled in the remaining group (23.31 ± 12.47) (p = 0.001). This shows that systemic trauma scores are also significant predictors in terms of mortality. While the average of GCS exitus was 3.43 ± 1.13 in patients, 12.42 ± 3.55 in survivors (p < 0.001). It was observed that the need for mechanical ventilation and mortality rates in intensive care of patients with GCS ≤ 8 were significantly higher. This finding supports that low GCS strongly reflects neurotrauma severity and poor prognosis. In addition, trauma scores such as PEWS and PTS have also been found to be significantly associated with mortality (p = 0.005 and p = 0.001, respectively). The mean PEWS in exitus patients was calculated as 7.14 ± 1.06; the mean PTS was calculated as 2.43 ± 2.60. These scores were found to be 2.66 ± 2.68 and 7.76 ± 2.96 in the remaining group, respectively. In the light of these data, it is seen that in addition to multi-systemic scoring systems such as PRISM III and PELOD, specific clinical indicators such as GCS and ISS also offer accuracy in mortality prediction in pediatric trauma patients. The integrated use of scoring systems plays a key role in optimizing patient management in pediatric intensive care practice and early identification of high-risk cases.

Various biomarkers are emphasized to predict prognosis and mortality in children with critical illness. Of these, lactate and albumin are two parameters that attract attention both because of their accessibility and their role in physiopathological processes. It has already been shown that the lactate level is closely related to mortality due to its reflection of tissue perfusion disorder and hypoxia; lactate clearance is an important indicator for monitoring the course of the disease [24]. On the other hand, hypoalbuminemia has also been associated with poor prognosis, reflecting conditions such as inflammation, capillary reakage, and malnutrition [25]. In recent years, the lactate/albumin ratio obtained by evaluating these two parameters together has been proposed because it provides a stronger prediction than the prognostic value they show when used alone [18]. In these studies of Varol et al., a significant relationship was found between mortality and lactate/albumin ratio in children with critical illness; It was reported that the risk of mortality increased 38.5 times if this rate was above 0.880. Similarly, in a study conducted in the adult patient group, it was shown that the lactate and lactate/albumin ratio was higher, and the albumin level was lower in patients with mortality [26]. In our study, we found that the levels of lactate (8.12±7.55 vs 2.85±1.85; p<0.001), pH (7.16±0.25 vs 7.34±0.95; p<0.001), SBE (-10.82±8.48 vs -2.18±5.54; p=0.043) and INR (1.50±0.45 vs 1.13±0.11; p<0.001) differed significantly in patients with excitus. According to ROC analysis, when the prognostic power of these parameters was evaluated, the highest AUC value belonged to the lactate and was found to be 0.848. Other parameters such as pH (AUC: 0.731), SBE (AUC: 0.807) and INR (AUC: 0.704) were also found to have reasonable predictive strength. The most remarkable finding is that the AUC value of the model created by combining these four biomarkers is calculated as 1,000. This shows that the model has full distinctive power in predicting mortality. These findings support that the multiple biomarker approach is a more powerful method than a single parameter in determining the risk of mortality in the critical patient group. The data obtained in this study show that laboratory parameters such as lactate, pH, SBE and INR are valuable biomarkers in predicting mortality, especially when combined. These results may contribute to the early risk classification and determination of treatment strategies of pediatric trauma patients.

Limitations

This study has some limitations. First, since our study has a single-centered and retrospective design, the generalility of the findings is limited. Conducting only in a pediatric intensive care unit belonging to a specific region may not represent patient groups in different socioeconomic and geographical conditions. In addition, retrospective examination of patient records may have caused some data deficiencies and information loss. Secondly, the sample size was limited in some subgroups (for example, rare types of trauma, such as firearm injury, asphyxia). This may have made it difficult to detect significant differences in statistical analyses and prevented some relationships from being revealed. Thirdly, in the analysis in which the relationship between biomarkers and mortality was evaluated, external factors (for example, underlying diseases, post-traumatic intervention times and applied treatment protocols) could not be sufficiently controlled. This can affect the prognostic value of some laboratory parameters. Finally, long-term patient results (neurological sequelae, quality of life, etc.) were not evaluated in our study. Focus only on the intensive care process and in-hospital mortality. For this reason, conclusions cannot be made about the long-term effects of trauma.

Strengths

This study has many strengths in terms of providing important information on the intensive care management and prognosis of pediatric trauma patients. In the study, a wide variety of variables from demographic information to laboratory parameters, from trauma mechanisms to scoring systems were evaluated, thus analyzing the clinical profile of trauma patients from a holistic perspective. The relationship of different scoring systems such as GCS, PRISM III, PELOD, PEWS and PTS with mortality was examined in detail and their prognostic value was compared. In this aspect, the study offers an original analysis that can contribute to clinical decision-making processes. The predictive power of biomarkers such as lactate, pH, SBE and INR on mortality was evaluated with ROC analyzed; It was revealed that the use of these parameters in combination has high predictive value. Region-specific trauma etiologies such as motorcycle accidents and drowning have been discussed in detail, and attention has been drawn to the risks of the adolescent age group. In this aspect, the study contributes to both the development of local health policies and targeted preventive strategies. Specific findings, such as the relationship between head and neck trauma and the need for mechanical ventilation, offer practical benefits in a way that guides clinical follow-up.

Conclusion

This study provides important findings on the epidemiology, clinical characteristics and prognostic indicators of pediatric trauma patients admitted to the pediatric intensive care unit. Our findings have revealed that trauma mechanisms, especially motorcycle accidents and drowning, are associated with high mortality rates. It reveals the need for the development of appropriate driving training programs for this age group and to make legal regulations on this subject. In addition, it was determined that laboratory parameters such as lactate, pH, standard base surplus (SBE) and INR differ significantly in relation to mortality. Among these parameters, it is seen that the highest prognostic value belongs to the lactate (AUC: 0.848), while the distinguishing power of the model in which these four biomarkers are used together (AUC: 1,000) was accurately determined. This supports that the use of multiple biomarkers in predicting mortality risk is a much more powerful method compared to individual criteria. The strong relationship between head and neck injuries and the need for mechanical ventilation emphasizes the need for early diagnosis, rapid intervention and intensive monitoring in this patient group. Effective use of scoring systems can improve patient management by facilitating the timely and accurate making of clinical decisions. In conclusion, our study reveals that early risk classification based on trauma mechanism, clinical scores and laboratory findings is of great importance in terms of reducing mortality and optimizing the treatment process in pediatric trauma patients. Public health-based approaches such as developing preventive strategies specific to the adolescent age group, increasing traffic safety awareness, swimming training and encouraging the use of protective equipment will contribute to reducing the regional trauma burden.

Suggestions for future research

Future studies should focus on multicenter, prospective designs to better understand the long-term outcomes of pediatric trauma patients. In addition, it would be beneficial to conduct research in areas such as preventive measures to reduce the frequency of trauma, especially pre-injury programs and safety education. Research on new biomarkers and advanced imaging techniques to improve trauma diagnosis and management is also valuable.

Conflict of Interest: The authors declare that they have no known financial interests or personal relationships that could have appeared to influence the conduct of this study.

Author Contributions		Author Initials
SCD	Study Conception and Design	FB,CD
AD	Acquisition of Data	CD,FB
AID	Analysis and Interpretation of Data	FB, TAB
DM	Drafting of Manuscript	FB, TAB
CR	Critical Revision	FB, TAB

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