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Integrating Clinical and Laboratory Markers to Predict Transfusion in Pediatric Trauma Patients

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Abstract

Trauma-related hemorrhage represents a leading contributor to avoidable deaths in pediatric patients and often necessitates prompt transfusion decisions. Unlike adults, children may maintain hemodynamic stability until significant blood loss occurs, making early recognition of transfusion needs particularly challenging. This investigation sought to determine dependable clinical and laboratory predictors of blood transfusion during the initial 24-hour period of pediatric trauma and to establish a practical risk stratification tool to aid emergency decision-making. This retrospective study included pediatric trauma patients under 18 years of age who were admitted to a Pediatric Intensive Care Unit. Clinical and laboratory data at admission were recorded, and patients were grouped based on whether they received blood transfusions during the initial 24-hour period. Univariate and multivariate logistic regression analyses were conducted to determine independent predictors. Receiver operating characteristic curve analysis was employed to establish optimal threshold values and develop a combined risk score for transfusion prediction. Among 95 pediatric trauma patients, 34.7% required blood transfusion within 24 hours. Transfused patients had significantly lower pediatric trauma scores, higher glucose levels, lower platelet counts, and were more frequently intubated. Multivariate analysis identified intubation, glucose, and platelet count as independent predictors of transfusion. A combined risk score incorporating these variables demonstrated high discriminative ability (area under the curve=0.831). Risk stratification revealed transfusion rates of 3.8% in low-risk patients, 30.2% in moderate-risk patients, and 100% in high-risk patients. The combination of intubation, glucose, and platelet count provided a simple yet effective tool for predicting transfusion needs in pediatric trauma. The resulting risk score outperformed individual parameters and allowed for early identification of high-risk patients. This model may help guide timely transfusion decisions and optimize care in emergency settings. Prospective validation is warranted to confirm its clinical utility and broader applicability.

Keywords: Pediatric trauma, blood transfusion, predictive biomarkers, intensive care

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Introduction

Trauma-related hemorrhage remains among the primary contributors to avoidable deaths in pediatric patients worldwide. In trauma settings, reduction in circulating blood volume secondary to bleeding is the most common cause of shock. Hemorrhagic shock stands as the second leading cause of trauma-related deaths after traumatic brain injury and represents a frequently treatable condition when identified promptly. This makes early identification and management of hemorrhage crucial for improving outcomes in pediatric trauma cases[1,2].

This topic was chosen due to the critical importance of timely blood transfusion decisions in pediatric trauma care. Unlike adult patients, children possess unique physiological responses to blood loss that can mask significant hemorrhage until critical decompensation occurs. The ability to predict which pediatric trauma patients will require blood transfusion during the initial 24-hour period could significantly impact patient outcomes and resource allocation in emergency settings[3-5].

Highlights

- A novel risk score predicts transfusion needs in pediatric trauma patients.
- Intubation, glucose, and platelet count are independent predictors.
- The combined score shows strong discriminative ability (area under the curve=0.831).
- Risk stratification accurately identifies high-risk patients.
- Early prediction may guide transfusion decisions and improve outcomes.

The primary problem addressed in this study is the difficulty in accurately predicting blood transfusion needs in pediatric trauma patients. Blood loss exceeding 30% reduces oxygen delivery and increases anaerobic glycolysis, resulting in tissue hypoperfusion manifested as lactic acidosis. Based on this pathophysiology, lactic acidosis has been strongly associated with trauma mortality. Base deficit has also been utilized as a prominent marker of metabolic acidosis and tissue hypoperfusion. Additionally, vital signs including heart rate and systolic blood pressure serve as readily obtainable clinical indicators for assessing shock. The shock index, computed as the ratio of heart rate to systolic blood pressure, has emerged as a useful tool for monitoring acute circulatory failure[6,7].

Metabolic stress markers have gained recognition as important indicators in trauma patients. Glucose elevation during trauma reflects the body's stress response and has been associated with injury severity. Furthermore, pediatric-specialized scoring systems, including the pediatric trauma score, have been developed to provide comprehensive assessment of injury severity in children. Coagulation abnormalities, reflected by the elevated international normalized ratio (INR), frequently accompany severe trauma and significantly impact transfusion decisions[8,9].

To address this clinical challenge, a retrospective analysis was conducted examining multiple clinical and laboratory parameters in pediatric trauma patients. The investigation was structured to assess the predictive performance of various biomarkers and clinical indicators for blood transfusion needs. Patients, were systematically compared by examining differences between those who received transfusions and those who did not, with comprehensive analysis of their clinical characteristics and outcomes[1,10].

In our clinical experience, we observed that traditional vital signs alone may be insufficient for accurately predicting transfusion needs in pediatric trauma patients, as children can maintain hemodynamic stability until significant blood loss occurs. We hypothesized that combining clinical and laboratory parameters beyond hemoglobin levels would enhance the prediction of blood transfusion needs in pediatric trauma patients. This study aimed to identify reliable predictors of blood transfusion needs within 24 hours, determine optimal cut-off values for clinical application, and evaluate the independent contribution of various parameters. Through this research, we sought to develop a practical approach that could improve early recognition of children requiring blood transfusion in emergency settings.

Materials and Methods

This retrospective investigation was performed at the Pediatric Intensive Care Unit (PICU) of Erciyes University Medical Faculty Hospital between June 2017 and September 2021. The study was approved by the Ethics Committee of Erciyes University Medical Faculty (approval number: 2021/734, date: 03.11.2021). All pediatric trauma patients younger than 18 years who were admitted to the PICU were retrospectively reviewed. Patients with complete medical records who survived at least one hour after admission were incorporated into the study. Exclusion criteria included incomplete medical records, death within the first hour of admission, patients who were transferred after receiving blood products at other centers, and those with known hematological disorders or bleeding diathesis.

Patient data were extracted from electronic medical records and comprised demographic characteristics (age, gender, weight), trauma etiology, affected organ systems, type of head trauma, presence of pneumothorax, indication for intubation, mechanical ventilation duration, surgical interventions, oxygen support requirements, pediatric trauma score, PRISM score, duration of stay in the intensive care unit, total hospital stay duration, and inotropic support needs. Vital signs encompassing heart rate, respiratory rate, systolic and diastolic blood pressure, and oxygen saturation were recorded at admission. Shock index was computed by dividing heart rate by systolic blood pressure at admission. Laboratory values were collected from blood samples obtained at the time of admission to the PICU before any interventions. The following tests were documented: complete blood count, blood glucose, liver enzymes [aspartate aminotransferase (AST), alanine aminotransferase (ALT), kidney function tests (blood urea nitrogen), creatinine], inflammatory markers (C-reactive protein, procalcitonin), coagulation parameters (INR), and blood gas analysis including

lactate, pH, and base excess.

Patients were categorized into two groups based on blood transfusion requirement within the first 24 hours of admission: the transfusion group, (patients who received blood transfusion) and the non-transfusion group (patients who did not receive blood transfusion). The primary outcome was the need for blood transfusion within 24 hours of admission to the PICU, determined by attending physician assessment of clinical and laboratory parameters.

Transfusion decisions during the study period were based on clinical judgment considering hemoglobin levels, hemodynamic status, ongoing bleeding, and anticipated surgical blood loss. General institutional guidelines suggested transfusion consideration for hemoglobin levels between 7-8 g/dL in stable patients, or 8-10 g/dL with active bleeding or instability, though final decisions were left to the discretion of the attending physician.

Statistical Analysis

All statistical computations were performed using TURCOSA statistical software (Turcosa Analytics Ltd. Co., Türkiye). Post-hoc power analysis using G*Power 3.1 revealed that with 33 transfused and 62 non-transfused patients, the study had 85% power to detect a medium effect size (Cohen's d=0.65), with α=0.05. Data normality was evaluated through the Shapiro-Wilk test. Parametric data were expressed as mean ± standard deviation, while non-parametric data were presented as median and interquartile range. Categorical data were summarized as frequencies and percentages. Group comparisons utilized appropriate statistical methods. Non-parametric continuous variables were analyzed using the Mann-Whitney U test, while categorical variables were examined using chi-square or Fisher's exact tests. Univariate logistic regression identified factors associated with transfusion needs. Variables achieving $p<0.10$ in univariate analysis were entered into multivariate logistic regression using backward elimination.

Receiver operating characteristic (ROC) curve analysis determined optimal thresholds for continuous variables in predicting transfusion requirements. Area under the curve (AUC) values were calculated with 95% confidence intervals (CIs). DeLong's method facilitated pairwise AUC comparisons. The diagnostic performance for categorical variables was evaluated using contingency tables. A composite risk score incorporated independent predictors from multivariate analysis. Point allocation reflected odds ratios (ORs) and clinical relevance. Chi-square trend analysis evaluated risk stratification performance, while ROC analysis assessed the composite score's discriminative capacity. Statistical significance was defined as $p<0.05$.

Results

Patient Characteristics and Group Comparisons

Ninety-five pediatric trauma patients were included in this investigation. Thirty-three patients (34.7%) received blood transfusion within 24 hours, while 62 patients (65.3%) did not require transfusion. The median age was 4 years (2-11) in the transfusion group versus 7 years (4-13.25) in the non-transfusion group (p=0.119). Male patients represented 51.5% of the transfusion group compared to 77.4% of the non-transfusion group (p=0.010). Body weight showed no significant difference between groups (p=0.386). Traffic accidents were the predominant trauma mechanism in the transfusion group (67.7% vs. 48.3%), though the overall distribution of mechanisms did not reach statistical significance (p=0.097). No penetrating trauma cases were observed. Patients requiring transfusion exhibited significantly lower pediatric trauma scores (3.5 vs. 7, $p<0.001$), lower Glasgow Coma Scale scores (5 vs. 12, $p<0.001$), and higher PRISM scores (13 vs. 0, $p<0.001$). Heart rate (126 vs. 114 bpm, p=0.042) and shock index (1.2 vs. 1.0, p=0.028) were elevated in transfused patients. Systolic and diastolic blood pressure demonstrated no significant differences between groups. Laboratory values at PICU admission demonstrated several significant differences. Hemoglobin levels were reduced in transfused patients (10.6 vs. 12.3 g/dL, $p<0.001$), and platelet counts were also reduced in transfused patients (307 vs. 350.5 $\times 10^3/\mu L$, p=0.023). Glucose levels were increased (212 vs. 132.5 mg/dL, $p<0.001$), lactate was higher (2.81 vs. 2.3 mmol/L, and p=0.013), pH was lower (7.32 vs. 7.4, $p<0.001$), and base excess was more negative (-4.9 vs. -3 mEq/L, p=0.033). Liver enzymes were significantly elevated in the transfusion group: AST (259 vs. 55.3 U/L, $p<0.001$) and ALT (123 vs. 29.15 U/L, $p<0.001$). INR (1.27 vs. 1.115, $p<0.001$) and creatinine levels (0.55 vs. 0.45 mg/dL, p=0.009) were higher in transfused patients.

Transfused patients required more intensive interventions. Intubation (84.8% vs. 24.2%, $p<0.001$), surgical procedures (57.6% vs. 16.1%, $p<0.001$), and inotropic support (42.4% vs. 6.5%, $p<0.001$). Multiple organ involvement was more common in transfused patients (87.9% vs. 54.8%, p=0.025). PICU length of stay was longer in the transfusion group (6.5 vs. 3 days, p=0.002), as was the total hospital stay (14 vs. 8 days, p=0.002). **Table 1** presents group comparisons.

Predictors of Blood Transfusion Requirement

Univariate analysis identified significant associations between transfusion requirement and pediatric trauma score (OR=1.61, 95% CI: 1.31-1.97, $p<0.001$), glucose (OR=1.02, 95% CI: 1.01-1.03, $p<0.001$), platelet count (OR=1.00, 95% CI: 1.00-1.00, p=0.018), shock index (OR=0.18, 95% CI: 0.05-0.70, p=0.013), and intubation (OR=17.54, 95% CI: 5.75-53.51, $p<0.001$).

Multivariate backward Wald analysis revealed three independent predictors: intubation, identified as the strongest predictor (OR=7.69, 95% CI: 2.25-26.32, p=0.001), glucose levels (OR=1.02, 95% CI: 1.01-1.03, p=0.017), and platelet count, which trended toward significance (OR=1.00, 95% CI: 1.00-1.00, p=0.092). **Table 2** displays the complete results.

ROC Analysis and Diagnostic Performance

Five continuous variables were evaluated for transfusion prediction within 24 hours. pediatric trauma score achieved the highest discriminative ability (AUC=0.832, 95% CI: 0.741-0.901, $p<0.001$) with an optimal cut-off of ≤5 (sensitivity 78.1%, specificity 80.6%). Glucose

demonstrated strong performance (AUC=0.795, 95% CI: 0.699-0.871, p<0.001) with cut-off ≥187 mg/dL (sensitivity 78.8%, specificity 82.3%).

Platelet count showed moderate ability (AUC=0.642), lactate levels demonstrated an AUC=0.655, and shock index showed an AUC=0.637. Intubation status revealed a significant association (χ^2=31.98, p<0.001) with the highest sensitivity (84.8%) and negative predictive value (90.4%). Pairwise comparisons showed that the pediatric trauma score outperformed both lactate and the shock index, while glucose exceeded the performance of the shock index. **Table 3** contains diagnostic metrics.

Combined Risk Score Development and Validation

A three-component risk score was constructed using multivariate predictors: intubation (2 points), glucose >187 mg/dL (2 points), and platelet count <321,000/μL (1 point), thus creating a range of 0 to 5 points.

Risk stratification created three distinct groups with progressively increasing transfusion rates: low risk (0 points, n=26, 27.4%) with 3.8% transfusion rate; moderate risk (1-2 points, n=53, 55.8%) with 30.2% transfusion rate; and high risk (3-5 points, n=16, 16.8%), where all patients required transfusion. While the high-risk group demonstrated a 100% transfusion requirement, the interpretation of this finding should be tempered by the limited sample size (n=16) in this stratum.

The combined score achieved an AUC=0.831 (95% CI: 0.744-0.918, p<0.001), exceeding individual parameters. An optimal cut-off of ≥1.5 points yielded 97.0% sensitivity and 40.3% specificity. High-risk patients demonstrated a 100% transfusion requirement. In contrast, low-risk patients exhibited a 96.2% negative predictive value. **Table 4** outlines the complete results.

Table 1.
Comparison of demographic data, clinical scores, vital signs and laboratory values between transfusion and non-transfusion groups

Variables	Transfusion group (n=33)	Non-transfusion group (n=62)	p-value
Demographics			
Sex (male), n (%)	17 (51.5)	48 (77.4)	0.010*
Age (years)	4 (2-11)	7 (4-13.25)	0.119
Weight (kg)	25 (15-35)	25 (15-42.5)	0.386
Trauma mechanisms			0.097
Traffic accidents, n (%)	21 (67.7)	28 (48.3)	
Falls from height, n (%)	8 (25.8)	20 (34.5)	
Other mechanisms, n (%)	2 (6.5)	10 (17.2)	
Clinical scores			
Pediatric trauma score	3.5 (1-5)	7 (6-9)	<0.001*
Glasgow coma scale	5 (3-10)	12 (10-13)	<0.001*
PRISM score	13 (4-17.75)	0 (0-4.5)	<0.001*
Vital signs			
Heart rate (bpm)	126 (106.5-156)	114 (95.75-132.25)	0.042*
Shock index	1.2 (0.90-1.57)	1.0 (0.85-1.21)	0.028*
Laboratory values			
Hemoglobin (g/dL)	10.6 (9.4-11.4)	12.3 (11.2-13.1)	<0.001*
Platelet count (×10³/μL)	307 (242.5-418.5)	350.5 (288.25-430.75)	0.023*
Glucose (mg/dL)	212 (189-294)	132.5 (112.75-161.75)	<0.001*
AST (U/L)	259 (111.85-640.5)	55.3 (36.675-149.75)	<0.001*
ALT (U/L)	123 (55.5-400.5)	29.15 (18.175-99.225)	<0.001*
Creatinine (mg/dL)	0.55 (0.425-0.765)	0.45 (0.36-0.5925)	0.009*
INR	1.27 (1.17-1.485)	1.115 (1.04-1.18)	<0.001*
pH	7.32 (7.225-7.4)	7.4 (7.36-7.47)	<0.001*
Base excess (mEq/L)	-4.9 (-9.35 to -1.8)	-3 (-5.5 to -1.75)	0.033*
Lactate (mmol/L)	2.81 (2.2-4.835)	2.3 (1.4925-3.0275)	0.013*
Clinical interventions			
Intubation, n (%)	28 (84.8)	15 (24.2)	<0.001*
Surgery, n (%)	19 (57.6)	10 (16.1)	<0.001*
Inotropic support, n (%)	14 (42.4)	4 (6.5)	<0.001*
Outcomes			
Multiple organ involvement, n (%)	29 (87.9)	34 (54.8)	0.025*
ICU length of stay (days)	6.5 (3-11.75)	3 (2-6.5)	0.002*
Hospital length of stay (days)	14 (8.25-28.75)	8 (5-13.5)	0.002*

Data are presented as median (Q1-Q3) for continuous variables and n (%) for categorical variables. *Mann-Whitney U test for continuous variables, Chi-square test for categorical variables, ICU: Intensive care unit, PRISM: Pediatric risk of mortality, INR: International normalized ratio, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, BUN: Blood urea nitrogen, CRP: C-reactive protein

Discussion

This study aimed to identify reliable predictors of blood transfusion needs within the initial 24 hours of admission in pediatric trauma patients and to develop a practical risk assessment tool for use in emergency settings. The results supported our hypothesis that integrating clinical and laboratory parameters beyond hemoglobin levels would enhance the prediction of transfusion needs. Specifically, intubation status, elevated glucose levels, and reduced platelet count emerged as independent predictors of transfusion, and their integration into a combined risk score demonstrated excellent discriminative performance (AUC=0.831), accurately identifying patients at elevated risk for transfusion.

To the best of our knowledge, this is the first study to propose a validated composite risk score for predicting blood transfusion needs in pediatric trauma using widely available admission parameters. The predictive performance of the combined score surpassed that of any single variable. Notably, all patients classified as high-risk required transfusion, while those in the low-risk category had a high likelihood of avoiding it. This three-tiered stratification provides clinicians with a simple yet powerful framework for early identification and prioritization of children who may benefit from prompt transfusion in acute care settings.

Among the independent predictors, intubation proved to be the most significant. This association likely reflects the close link between respiratory compromise and the

Table 2.
Univariate and multivariate logistic regression analysis for factors associated with blood transfusion in pediatric trauma patients

Variables	Univariate analysis			Multivariate analysis		
	OR	95% CI	p-value	OR	95% CI	p-value
Pediatric trauma score	1.61	1.31-1.97	**<0.001**	0.87	0.66-1.13	0.288
Lactate (mmol/L)	0.82	0.66-1.01	0.063	1.05	0.78-1.42	0.733
Glucose (mg/dL)	1.02	1.01-1.03	**<0.001**	1.02	1.01-1.03	**0.017**
Platelet count (×10³/μL)	1.00	1.00-1.00	**0.018**	1.00	1.00-1.00	0.092
Shock index	0.18	0.05-0.70	**0.013**	3.05	0.48-19.39	0.237
Intubation (yes vs. no)	17.54	5.75-53.51	**<0.001**	7.69	2.25-26.32	**0.001**

Bold values indicate statistically significant associations (p<0.05).
OR: Odds ratio, CI: Confidence interval, INR: International normalized ratio, NS: Not significant (removed by backward Wald method). Multivariate analysis was performed using backward Wald method. Variables with p>0.10 were sequentially removed from the model. Final model included intubation, glucose, and platelet count as predictors of transfusion requirement

Table 3.
ROC analysis and diagnostic performance of parameters predicting blood transfusion

Parameter	AUC	95% CI	p-value	Optimal cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pediatric trauma score	0.832	0.741-0.901	<0.001	≤5	78.1	80.6	67.6	87.7
Glucose (mg/dL)	0.795	0.699-0.871	<0.001	≥187	78.8	82.3	70.3	87.9
Platelet count (×10³/μL)	0.642	0.537-0.738	0.021	≤321,000	60.6	64.5	47.6	75.5
Lactate (mmol/L)	0.655	0.550-0.750	0.009	≥2.38	72.7	56.5	47.1	79.5
Shock index	0.637	0.532-0.733	0.037	≥1.26	45.5	83.9	60.0	74.3
Intubation*	-	-	<0.001	Present	84.8	75.8	65.1	90.4

AUC: Area under curve, PPV: Positive predictive value, NPV: Negative predictive value, ROC: Receiver operating characteristic, CI: Confidence interval, *Intubation analyzed using chi-square test (χ^2=31.98, p<0.001)

Table 4.
Combined risk score for predicting blood transfusion requirement

Risk factor/category	Criteria/range	Points	n (%)	Transfusion rate	Performance metrics
Risk score components					
Intubation	Present	2	-	-	OR: 7.69 (2.25-26.32)
Glucose	>187 mg/dL	2	-	-	OR: 1.01 (1.00-1.02)
Platelet count	<321,000/μL	1	-	-	OR: 1.00 (1.00-1.00)
Risk categories					
Low risk	0 points	-	26 (27.4%)	3.8% (1/26)	NPV: 96.2%
Moderate risk	1-2 points	-	53 (55.8%)	30.2% (16/53)	-
High risk	3-5 points	-	16 (16.8%)	100.0% (16/16)	PPV: 100%
Overall performance					
Combined score	0-5 points	-	95 (100%)	34.7% (33/95)	AUC: 0.831 (0.744-0.918)
Optimal cut-off	≥1.5 points	-	-	-	Sensitivity: 97.0%
Statistical significance	-	-	-	-	χ^2=41.49, p<0.001

Risk score developed from multivariate logistic regression coefficients. Points assigned based on odds ratios and clinical significance. AUC: Area under curve, PPV: Positive predictive value, NPV: Negative predictive value, OR: Odds ratio

severity of traumatic injury. A markedly higher proportion of transfused patients required intubation, underscoring the role of airway management as both a marker and a consequence of physiological decompensation in severely injured children. These findings are in line with reports from adult trauma cohorts, where airway intervention has also been associated with increased transfusion needs, reinforcing the relevance of this marker across age groups.

Glucose elevation also showed strong predictive value for transfusion. Hyperglycemia, as part of the systemic stress response to trauma, reflects the activation of neuroendocrine and inflammatory pathways associated with injury severity. Our findings align with previous pediatric studies reporting that elevated glucose levels are associated with more severe trauma and poorer clinical outcomes. Tsai et al.[11] demonstrated, using propensity score-matched analysis, that stress-induced hyperglycemia significantly impacted outcomes in children with trauma, while Tuggle et al.[12] showed that hyperglycemia was associated with increased infection rates in pediatric trauma patients. Thus, glucose at admission may serve not only as a metabolic marker but also as a practical indicator for transfusion triage.

The association between lower platelet counts and increased transfusion requirement underscores the role of early coagulopathy in trauma-related hemorrhage. Although platelet count alone had moderate discriminative ability, its inclusion in the risk score enhanced overall performance. This finding highlights the possibility that early coagulation disturbances may precede overt bleeding and transfusion need in pediatric trauma patients[13].

The pediatric trauma score demonstrated the highest individual discriminative ability among all evaluated parameters (AUC=0.832), underscoring its value as a comprehensive indicator of injury severity in children. However, pediatric trauma score was not retained in the final multivariate model due to collinearity with the included variables. Since pediatric trauma score components include airway status, systolic blood pressure, and neurological status, which overlap with our model variables (intubation, hemodynamic parameters, and altered consciousness), including pediatric trauma score would have introduced multicollinearity and potentially biased the regression analysis.

We therefore retained only the most clinically straightforward and independently significant predictors. Several recent pediatric trauma studies have similarly emphasized the prognostic value of trauma scores and physiological markers in children. For instance, Wendling-Keim et al.[14] highlighted the utility of trauma scores for outcome prediction in pediatric polytrauma, while Lammers et al.[15] and Choi et al.[16] reported the predictive accuracy of pediatric shock indices and their age-adjusted modifications. In addition, coagulopathy and lactate dynamics have been identified as important predictors of adverse outcomes in pediatric trauma[17-19]. These findings support our results and indicate that integrating routinely available clinical and laboratory parameters into structured tools can improve risk stratification specifically in children.

An unexpected finding in our cohort was the higher proportion of female patients in the transfusion group (48.5% vs. 22.6%, p=0.010). While this contrasts with typical pediatric trauma demographics where males predominate, the interpretation of this finding requires caution given our sample size. Previous studies have shown conflicting results regarding sex-based differences in pediatric transfusion requirements. Some reports suggest that anatomical differences in pelvic vasculature and blood volume relative to body size may influence bleeding patterns, though these mechanisms remain unproven in pediatric populations[20,21]. The observed difference in our study may also reflect chance variation or unmeasured confounders such as injury patterns specific to each sex. This finding requires validation in larger, multicenter studies before drawing definitive conclusions about sex-based transfusion risk.

The need for transfusion was associated with increased morbidity. Patients who received transfusions had longer intensive care and hospital stays and required more frequent surgical interventions and inotropic support, reflecting greater injury severity and clinical complexity[22]. These outcomes highlight the importance of early and accurate identification of patients at risk for transfusion, as timely intervention may reduce complications and resource burden.

The strong predictive performance of our combined risk score addresses a critical unmet need in pediatric trauma care. Traditional vital signs often fail to detect early blood loss in children due to their robust compensatory mechanisms. By integrating intubation status, glucose, and platelet levels into a practical tool, our study provides a structured approach to guide early transfusion decisions, potentially improving triage accuracy and clinical outcomes.

Important methodological constraints require acknowledgment. The retrospective nature of this study restricts causal inference capabilities and introduces potential selection bias. These findings, from a single-institution investigation conducted at a tertiary care center, have inherent limitations in generalizability. Our patient population, referral patterns, and institutional protocols may differ substantially from other healthcare facilities, particularly community hospitals or centers in different geographic regions. The risk score's performance may vary in settings with different case-mix severity, resource availability, or transfusion thresholds. Furthermore, the limited sample size within the high-risk stratum (n=16) significantly constrains the robustness of conclusions for this subgroup. While all 16 high-risk patients required transfusion (100%), this small sample raises concerns and limits CI precision due to potential overfitting. External validation in larger, multicenter cohorts is essential before clinical implementation of this scoring system.

Conclusion

In summary, we established and validated a practical, three-component risk assessment tool for predicting blood transfusion requirements in pediatric trauma patients during the first 24 hours of admission. The integration of intubation status, glucose levels, and platelet count

demonstrated strong discriminative ability and offered a valuable framework for early risk stratification. Future multicenter, prospective investigations are required to validate this scoring system and evaluate its impact on clinical workflows. Incorporating this tool into automated systems could further streamline emergency care in pediatric trauma.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of Erciyes University Medical Faculty (approval number: 2021/734, date: 03.11.2021).

Informed Consent: Because the study was designed retrospectively no written informed consent form was obtained from the patients.

Footnotes

Author Contributions: Dündar MA: Surgical and Medical Practies, Concept, Design, Data Collection or Processing, Analysis or Interpretation, Literature Search, Writing; Ceran E: Surgical and Medical Practies, Concept, Analysis or Interpretation; Tekin Can S: Surgical and Medical Practies, Design, Data Collection or Processing, Akyıldız BN: Surgical and Medical Practies, Concept.

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