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Clinical and Laboratory Markers to Predict the Need for Intubation in Pediatric Trauma

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ABSTRACT

Objective: Emergency tracheal intubation is a critical component of acute management in children with traumatic injuries. This study aimed to determine which clinical and laboratory markers are most predictive of the need for airway intervention in this vulnerable population.

Materials and Methods: This observational cohort analysis included 96 pediatric trauma patients under 18 years of age admitted to a university hospital Pediatric Intensive Care Unit (PICU). Demographic data, trauma characteristics, clinical parameters, and laboratory markers were analyzed. Statistical analyses included logistic regression and receiver operating characteristic (ROC) analysis to identify predictors of intubation.

Results: Among the 96 pediatric trauma patients, 45.8% required intubation. Female patients had significantly higher intubation rates (45.5%) compared to males (36.9%) (p=0.011). Trauma etiology differed significantly, with traffic accidents being more common among intubated patients, while falls from height were more frequent in non-intubated patients (p=0.007). Patients with multiple system injuries had an increased likelihood of intubation (p=0.004). Intubated patients had markedly higher blood glucose level, aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatinine, procalcitonin, international normalized ratio (INR), and lactate levels, while platelet counts were significantly decreased (p<0.001, p=0.036, p=0.039, p=0.026, p=0.002, p=0.007, p=0.003, and p=0.031, respectively). Logistic regression identified female sex, elevated blood glucose, decreased platelet count, and blood transfusion requirement as independent predictors. Intubated patients had significantly longer PICU stays (7.0 vs. 3.0 days, p<0.001) and overall hospital stays (14.5 vs. 7.0 days, p<0.001).

Conclusion: Female sex, motor vehicle accidents, drowning, and multisystem trauma were significantly associated with an increased risk of intubation. Key laboratory predictors included elevated blood glucose levels, decreased platelet count, and the need for blood transfusion. These markers can help guide early airway management decisions in pediatric trauma care.

Keywords: Intubation, multiple trauma, pediatrics, risk factors.

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INTRODUCTION

Pediatric trauma remains a leading cause of global childhood morbidity and mortality, often necessitating prompt and effective airway support to ensure adequate oxygen delivery and ventilation. In critically injured children, emergency tracheal intubation (ETI) is frequently required due to conditions such as hypoxia, hypoventilation, or compromised airway protection.[1,2] However, the decision to proceed with intubation is complex, as multiple clinical and physiological factors influence the need for airway intervention during the initial phase of resuscitation.[3]

One of the most common reasons for endotracheal intubation in pediatric trauma is severe traumatic brain injury (TBI), as compromised cerebral oxygenation is strongly associated with adverse neurological outcomes and increased mortality risk.[4] Delays in establishing a secure airway may exacerbate secondary brain injury, leading to further deterioration. Additionally, failed or inadequate ETI attempts can result in complications such as hypoxia, hypotension, and aspiration, further worsening patient prognosis.[5] Therefore, determining both the necessity and optimal timing of intubation is critical in pediatric trauma care.[6]

The optimal approach to prehospital airway management in pediatric trauma remains a matter of debate, particularly in settings without specialized pediatric intensive care.[7] While early intubation may be beneficial in selected cases, unnecessary or poorly executed intubation can lead to iatrogenic complications, including ventilator-associated lung injury and prolonged mechanical ventilation.[8] Determining reliable clinical and biochemical indicators that signal the necessity for intubation can help guide clinical decisions, minimize unwarranted procedures, and improve patient outcomes.[9] Currently, intubation practices in pediatric trauma are largely based on physician experience and general assessment tools such as the Glasgow Coma Scale (GCS), respiratory rate, and peripheral oxygen saturation. However, these guidelines lack the specificity required for individual patient assessment, particularly in the heterogeneous pediatric trauma population.[10]

Despite advancements in trauma care, there remains a need to refine intubation criteria for pediatric trauma patients. Current guidelines often rely on clinical judgment, yet objective indicators are needed to improve decision-making. This study aims to assess whether specific clinical findings and laboratory values can serve as predictors for intubation in children with trauma, ultimately contributing to better clinical decision-making and improved outcomes.

KEY MESSAGES

- Early recognition of intubation predictors can improve outcomes in pediatric trauma patients.
- Female sex, motor vehicle accidents, drowning, and multisystem trauma were significantly associated with increased intubation risk.
- Elevated blood glucose level, INR, and lactate levels, decreased platelet count, and transfusion requirement may guide timely intubation decisions in critically injured children.

MATERIALS AND METHODS

This retrospective study was conducted in the Pediatric Intensive Care Unit (PICU) of Erciyes University Medical Faculty Hospital. The study included pediatric patients under 18 years of age who were admitted for trauma between July 2016 and September 2021. The study protocol was approved by the Ethics Committee of Erciyes University (approval number: 2022/29), and all procedures were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki.

Patient Selection and Data Collection

Patients were included in the study if they were admitted due to trauma and were under 18 years of age at the time of hospitalization. Trauma was defined as a physical injury resulting from external forces, with severity assessed using the Pediatric Trauma Score (PTS). Exclusion criteria included non-trauma-related admissions and cases with incomplete medical records. Missing data were handled using multiple imputation techniques for variables with less than 10% missing values; patients with more than 10% missing data across key variables were excluded from the analysis.

The primary outcome in this study was whether the patient underwent endotracheal intubation within the first 24 hours following trauma. Secondary endpoints included length of stay in the intensive care unit (ICU), in-hospital mortality, and the requirement for surgical procedures. Data collection included demographic variables (age, sex, and weight), trauma characteristics (mechanism of injury, affected anatomical systems, type of head trauma, and presence of pneumothorax), and clinical parameters (requirement for surgical intervention, PTS, Pediatric Risk of Mortality Score [PRISM], ICU length of stay, total hospital stay, inotropic support requirement, and body temperature).

Laboratory variables analyzed included glucose, hemoglobin concentration, leukocyte count (white blood cell count, WBC), platelet number, liver enzymes including alanine aminotransferase (ALT) and aspartate aminotransferase (AST), blood urea nitrogen (BUN), international normalized ratio (INR), procalcitonin, pH, base excess (BE), and lactate. All tests were performed on the initial blood samples obtained within one hour of hospital arrival, prior to any airway intervention, to ensure that results accurately reflected the patient's pre-intubation physiological status. Clinical outcomes and interventions, such as the need for blood transfusions, were also documented.

Statistical Analysis

Data analysis was performed using TURCOSA Statistics software (Turcosa Ltd. Co., www.turcosa.com.tr). Normality was assessed using both visual methods (histograms, Q-Q plots) and analytical tests (Shapiro-Wilk test). Variables conforming to a normal distribution were summarized as mean±standard deviation (SD), whereas non-normally distributed variables were reported as median values with interquartile ranges (IQR). To compare two independent groups, the independent samples t-test was applied for normally distributed data, and the Mann-Whitney U test was used for non-normally distributed variables. Categorical variables were analyzed using Pearson's chi-square test; when assumptions for this test were violated, Fisher's exact test was applied.

To explore variables associated with the need for intubation, both univariate and multiple binary logistic regression analyses were performed. Variables with p<0.25 in the univariate analysis were considered candidates for multivariate modeling. To avoid overfitting, a maximum of five variables were included, following the events-per-variable principle. Backward stepwise (Wald) elimination was applied to identify independent predictors. Findings were reported as odds ratios (OR) with 95% confidence intervals (CI). Receiver operating characteristic (ROC) analysis was used to evaluate the discriminative performance of selected variables, and Youden's index was applied to determine optimal cut-off points. A post-hoc power analysis was performed for the glucose variable. Based on an effect size of 0.69, an alpha level of 0.05, and a beta value of 0.1 (power=0.9), the required sample size was estimated at 90 participants (45 per group). A significance level of p<0.05 was considered statistically significant for all analyses.

RESULTS

A total of 96 pediatric trauma cases were included in the analysis. The mean age was 7.9±5.3 years. Males comprised 67.7% (n=65) of the cohort, while females accounted for 32.3% (n=31). Overall, 45.8% (n=44) of patients required intubation, whereas 54.2% (n=52) did not.

Comparison of Demographic, Clinical, and Laboratory Parameters Between Intubated and Non-Intubated Patients

No significant differences were found between intubated and non-intubated patients in terms of age (p=0.382), body temperature (p=0.461), heart rate (p=0.508), systolic blood pressure (p=0.997), diastolic blood pressure (p=0.788), or urine output (p=0.542). However, a significantly higher proportion of females required intubation (45.5%) compared to males (36.9%) (p=0.011). Both PTS and PRISM scores differed significantly between groups (p<0.001). The median PTS was 4.00 (1.00–5.00) in intubated patients versus 8.00 (7.00–9.00) in non-intubated patients, while the median PRISM score was 10.00 (6.00–14.75) in intubated patients compared to 2.00 (1.00–3.00) in non-intubated patients. The median ICU stay was longer in intubated patients (7.0 days) than in non-intubated patients (3.0 days), as was the total length of hospitalization (14.5 vs. 7.0 days; p<0.001 for both comparisons).

In terms of laboratory findings, hemoglobin level, BUN, and C-reactive protein (CRP) did not show statistically significant differences between the groups (p=0.317, p=0.303, and p=0.603, respectively). However, platelet counts were significantly lower in patients requiring intubation (p=0.031). Additionally, higher levels of blood glucose (p<0.001), AST (p=0.036), ALT (p=0.039), creatinine (p=0.026), procalcitonin (p=0.002), and INR (p=0.007) were observed in the intubated group. The median blood glucose level was 198.50 mg/dL (133.75–260.50) in intubated patients compared to 129.00 mg/dL (102.00–170.00) in non-intubated patients.

Arterial blood gas analysis also revealed significant differences: pH was lower in intubated patients (p=0.003), lactate concentrations were significantly higher (p=0.003), and base excess showed a greater deficit (p=0.031) in the intubated group. A comprehensive summary of these results is presented in Table 1.

Comparison of Clinical and Trauma Characteristics in Intubated Versus Non-Intubated Patients

Distinct clinical and trauma-related characteristics were observed between patients who underwent intubation and those who did not. Falls from height were more frequently reported among non-intubated patients (23 cases), whereas both in-vehicle and out-of-vehicle traffic accidents were more prevalent among intubated patients (16 cases each) (p=0.007). Additionally, drowning incidents were more common in the intubated group (five cases).

Patients requiring intubation were more likely to have multi-system injuries (37 cases), whereas isolated cranial injuries were more common in non-intubated patients (18 cases) (p=0.004). The need for surgical intervention was significantly

Table 1. Comparison of demographic, clinical, and laboratory parameters between intubated and non-intubated pediatric trauma patients

Parameter	Non-Intubated (n=52)	Intubated (n=44)	p
Age (years)	6.50 (3.25–12.00)	8.50 (2.25–14.00)	0.382
Sex (female/male)	11/41	20/24	0.011
Body temperature (°C)	36.44±0.46	36.47±0.79	0.461
Heart rate (bpm)	116.20±27.55	121.79±36.31	0.508
Systolic blood pressure (mmHg)	112.30±16.48	113.00±19.35	0.997
Diastolic blood pressure (mmHg)	64.90±10.81	64.74±13.22	0.788
Urine output (mL/kg/hour)	2.00 (1.43–2.75)	2.03 (1.50–3.03)	0.542
Pediatric trauma score (PTS)	8.00 (7.00–9.00)	4.00 (1.00–5.00)	<0.001
PRISM score	2.00 (1.00–3.00)	10.00 (6.00–14.75)	<0.001
ICU length of stay (days)	3.00 (1.25–4.75)	7.00 (3.00–11.00)	<0.001
Total hospital stay (days)	7.00 (5.00–12.00)	14.50 (8.00–26.75)	<0.001
Hemoglobin (g/dL)	11.79±1.57	11.30±2.31	0.317
Platelets (×10^3/mm^3)	362.00±117.00	314.00±93.00	0.031
Glucose (mg/dL)	129.00 (102.00–170.00)	198.50 (133.75–260.50)	<0.001
AST (U/L)	57.80 (35.48–324.25)	118.35 (54.75–355.75)	0.036
ALT (U/L)	28.40 (15.13–172.00)	72.50 (30.38–138.00)	0.039
BUN (mg/dL)	11.85 (9.43–14.55)	12.90 (10.93–14.98)	0.303
Creatinine (mg/dL)	0.45 (0.36–0.61)	0.57 (0.40–0.72)	0.026
CRP (mg/dL)	1.93 (0.42–7.87)	2.11 (0.29–15.10)	0.603
Procalcitonin (ng/mL)	0.12 (0.03–1.10)	2.12 (0.09–7.80)	0.002
INR	1.12±0.13	1.23±0.25	0.007
pH	7.41±0.08	7.30±0.19	0.003
Lactate (mmol/L)	2.27 (1.20–2.96)	2.80 (2.15–3.80)	0.003
Base excess (BE)	-3.00 (–5.50 to –1.60)	-4.80 (–9.15 to –1.55)	0.031

Data are presented as mean±standard deviation for normally distributed variables, and median (25th–75th percentile) for non-normally distributed variables. Categorical data are shown as n/N. Normality was assessed using the Shapiro-Wilk test. The independent samples t-test was used for normally distributed variables, the Mann-Whitney U test for non-normally distributed variables, and the chi-square test for categorical variables. **Variables are presented as median (interquartile range, IQR) in the original table. 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; BE: Base excess.

higher among intubated patients (19 cases) compared to non-intubated patients (11 cases) (p=0.020). Although the incidence of pneumothorax did not reach statistical significance (p=0.068), it was more frequently observed in intubated patients (26 cases).

A highly significant difference was observed in the pattern of head trauma, with combined bone and parenchymal injuries occurring more often in intubated patients (p<0.001). In addition, intubated patients required inotropic agents and blood transfusions at significantly higher rates (p<0.001 for both comparisons). A comprehensive summary of these findings is provided in Table 2.

Independent Predictors of Intubation: Findings from Multiple Logistic Regression

Among variables with p < 0.25 in the univariate analysis, five were selected for inclusion in the multivariate model based on clinical relevance and statistical criteria. After backward elimination, four variables remained as independent predictors (Table 3). Female sex was associated with a higher likelihood of intubation (OR=5.1, 95% CI: 1.4–18.7, p=0.015).

Elevated blood glucose levels, calculated per 10 mg/dL increase, were significantly associated with a higher risk of intubation (OR=1.2, 95% CI: 1.1–1.3, p=0.002). A decrease in platelet count, scaled per 10,000/mm^3, was also a significant

Table 2. Clinical and trauma-related parameters of intubated and non-intubated patients

Parameter	Intubated (n=44)	Non-Intubated (n=52)	p
Trauma etiology			**0.007**
Fall from height	5	23	
In-vehicle accident	16	8	
Out-of-vehicle accident	16	15	
Drowning	5	2	
Crushing/gunshot wound	2	4	
Affected systems			**0.004**
Cranial/single system	7	27	
Multiple systems	37	25	
Operation needed	19/44	11/52	**0.020**
Pneumothorax	26/44	21/52	**0.068**
Head trauma type			**<0.001**
Bone	5	13	
Parenchymal	9	5	
Bone + parenchymal	25	12	
No head trauma	5	22	
Inotrope use	19/44	0/52	**<0.001**
Transfusion	20/44	6/52	**<0.001**

Data are presented as counts (n) or ratios (n/N). p-values were calculated using the Chi-Square Test. Subcategories are listed under their respective main categories.

predictor (OR=1.2, 95% CI: 1.1–1.3, p=0.008). Patients who required blood transfusion had a markedly higher risk of intubation (OR=5.7, 95% CI: 1.6–19.9, p=0.006). Detailed results from both univariate and multivariate logistic regression analyses are presented in Table 3.

ROC Analysis of Predictive Markers for Intubation

ROC curve analysis was used to evaluate the discriminatory capacity of selected variables between intubated and non-intubated pediatric trauma patients. The blood glucose level cut-off point providing the best balance between sensitivity and specificity was 187 mg/dL, yielding 63.6% sensitivity and 80.4% specificity (area under the curve [AUC]=0.748, p<0.001). For the International Normalized Ratio, the optimal threshold was 1.24, with corresponding sensitivity and specificity values of 45.5% and 90.4%, respectively (AUC=0.662, p=0.006).

A base excess value of -7.5 showed 43.9% sensitivity and 98.0% specificity (AUC=0.631, p=0.042). Similarly, a pH level of 7.32 demonstrated 48.8% sensitivity and 92.2% specificity (AUC=0.682, p=0.002). The most informative lactate cut-off was calculated as 2.37 mmol/L, with 70.7% sensitivity and 62.7% specificity (AUC=0.680, p=0.001). Pairwise comparisons of AUC values did not reveal any statistically significant differences (p>0.05). A comprehensive summary of these results is presented in Table 4.

DISCUSSION

This study aimed to evaluate whether specific clinical and laboratory indicators could predict the need for intubation in pediatric trauma cases. The results showed that trauma mechanism, extent of systemic involvement, and certain laboratory parameters (particularly platelet count, glucose, and INR) were significantly associated with intubation status. Multiple regression analysis confirmed that female sex, elevated blood glucose levels, decreased platelet count, and the need for blood transfusion were strongly associated with higher intubation rates. Additionally, multi-system trauma was found to markedly increase the need for airway management. These outcomes support our initial assumption that select demographic, clinical, and biochemical markers can serve as reliable predictors for intubation in pediatric trauma populations.

The higher likelihood of intubation in patients with multiple systems affected by trauma underscores the critical impact of multisystem injuries. Previous studies have shown that such

Table 3. Univariate and multivariate logistic regression analyses for predictors of intubationatients

Variable	Univariate OR (95% CI)	p	Multivariate OR (95% CI)	p
Female sex	3.1 (1.3–7.6)	0.013	5.1 (1.4–18.7)	**0.015**
Multi-system trauma	0.2 (0.1–0.6)	0.003	–	–
Glucose (per 10 mg/dL increase)	1.2 (1.1–1.4)	<0.001	1.2 (1.1–1.3)	**0.002**
Platelet count (per 10,000/mm^3 decrease)	1.2 (1.1–1.3)	0.034	1.2 (1.1–1.3)	**0.008**
Base excess	0.9 (0.8–1.0)	0.015	–	–
Transfusion (yes)	12.2 (4.3–34.6)	<0.001	5.7 (1.6–19.9)	**0.006**

Gender reference: male sex. Transfusion reference: no transfusion. Glucose: per 10 mg/dL increase. Platelet: per 10,000/mm^3 decrease. OR: Odds ratio; CI: Confidence interval.

Table 4. ROC curve analysis for predictors of intubation

Variable and cut-off value	AUC (95% CI)	SEN (95% CI)	SPE (95% CI)	PPV (95% CI)	NPV (95% CI)	p
Glucose ≥187 mg/dL	0.748 (0.642–0.854)	63.6 (45.1–79.6)	80.4 (66.1–90.0)	66.7 (46.0–82.8)	78.3 (63.0–88.5)	<0.001
INR ≥1.24	0.662 (0.550–0.773)	45.5 (28.4–63.4)	90.4 (77.4–97.3)	71.4 (47.8–88.7)	74.5 (63.1–83.4)	0.006
Base excess ≤7.5	0.631 (0.515–0.747)	43.9 (26.5–62.3)	98.0 (88.5–99.9)	87.5 (58.3–98.0)	77.5 (66.0–86.0)	0.042
pH ≤7.32	0.682 (0.571–0.793)	48.8 (31.9–65.8)	92.2 (79.1–98.4)	75.0 (50.8–91.3)	75.3 (64.0–83.9)	0.002
Lactate ≥2.37	0.680 (0.574–0.774)	70.7 (55.5–82.4)	62.7 (49.0–74.7)	60.4 (46.3–72.9)	72.7 (58.1–83.7)	0.001

AUC: Area under curve; ROC: Receiver operating characteristic; CI: Confidence interval; SEN: Sensitivity; SPE: Specificity; PPV: Positive predictive value; NPV: Negative predictive value.

patients face greater risks of peri-intubation complications and mortality, reinforcing the severity of these injuries.[11–13] Our findings are consistent with these reports and highlight the need for aggressive airway management in such cases. The strong association observed between drowning and intubation aligns with prior research, emphasizing the importance of urgent airway intervention in drowning cases due to the high risk of respiratory failure.[14] Similarly, both in-vehicle and out-of-vehicle traffic accidents were significantly associated with higher intubation rates, consistent with studies reporting that severe trauma often necessitates intubation, particularly in patients with lower Glasgow Coma Scale scores.[15]

Higher blood glucose levels were also a key predictor of intubation in our study, echoing earlier findings linking hyperglycemia to worse outcomes in pediatric trauma patients.[16,17] Stress-induced hyperglycemia, commonly seen in trauma patients, reflects increased injury severity and may signal the need for critical interventions such as intubation. Our ROC analysis identified an optimal blood glucose cut-off with good sensitivity and specificity, offering a practical threshold for clinical decision-making.

Platelet count also emerged as another important predictor, with lower platelet levels increasing the likelihood of intubation. This is consistent with findings in traumatic brain injury patients, where thrombocytopenia was associated with poorer outcomes.[18] Furthermore, our study revealed that patients requiring transfusions had a significantly higher likelihood of intubation, suggesting that the need for transfusion may serve as an indicator of trauma severity.

In our study, female patients had significantly higher intubation rates compared to males. Multivariate analysis confirmed this association, with female sex emerging as an independent predictor of intubation. This finding is consistent with previous research suggesting poorer prognostic indicators among female trauma patients, including lower Glasgow Coma Scale scores, which may contribute to an increased need for critical interventions such as intubation.[19] Potential explanations include sex-specific physiological responses to stress, anatomical differences in airway structure, and sociocultural factors influencing injury patterns and healthcare-seeking behavior. The complex relationship between sex and trauma outcomes likely involves hormonal, immunological, and psychosocial dimensions that extend beyond the scope of the present study.

Our study also identified significant associations between intubation and various laboratory parameters. Blood gas abnormalities (pH, base excess, and lactate) demonstrated valuable predictive thresholds, consistent with research linking these markers to trauma severity.[20,21] ROC analysis revealed optimal cut-off values for these parameters with clinically useful sensitivity and specificity. Our study found significantly higher AST and ALT levels in intubated patients, reflecting trauma severity and metabolic stress, findings consistent with prior research on abdominal trauma.[22] Additionally, INR emerged as a useful predictor, with an optimal threshold providing good specificity.

A notable finding was the significantly longer ICU and hospital stays among intubated patients compared to non-intubated patients. More precise intubation criteria could have important cost-effectiveness implications, as unnecessary intubations increase healthcare expenditures through prolonged ICU stays and potential complications. Recent analyses have shown that mechanical ventilation significantly raises hospital costs, suggesting that optimizing intubation decision-making could yield both economic benefits and improved patient outcomes.[23]

Based on our findings, a clinical decision tool incorporating these predictors could help identify pediatric trauma patients who require intubation. Such a tool would integrate trauma mechanism, multisystem involvement, female sex, blood glucose levels, platelet count, and transfusion requirement to provide risk stratification during early trauma care. While prospective validation is needed, this approach could standardize care and benefit centers with limited pediatric critical care experience.

This study has several limitations, including its retrospective, single-center design, which limits generalizability. The relatively small sample size resulted in wide confidence intervals for some variables. Future multicenter studies with larger cohorts are needed to provide more precise effect size estimates for these important clinical predictors.

CONCLUSION

This study identified key clinical and laboratory predictors of intubation in pediatric trauma patients, including female sex, trauma mechanism (particularly motor vehicle accidents and drowning), elevated blood glucose levels, decreased platelet count, and blood transfusion requirement. The multivariate model confirmed that female sex, elevated blood glucose, thrombocytopenia, and transfusion requirement were independent predictors. Laboratory markers provided valuable thresholds for clinical decision-making. The significantly longer ICU and hospital stays in intubated patients highlight the impact on healthcare resource utilization. Early recognition of these factors is crucial for guiding airway management decisions in pediatric trauma care.

Ethics Committee Approval: The Erciyes University Clinical Research Ethics Committee granted approval for this study (date: 08.02.2022, number: 2022/29).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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