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Research Article

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Children's trauma score combined with blood lactate measurement provides clinical treatment guidance and prediction of recovery for children with compound injuries: a prospective study

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Abstract

Background: *Compound injuries in children are the leading cause of death and disability, and early and accurate assessment is crucial to optimize treatment. This study aimed to ex-plore the clinical value of pediatric trauma score (PTS) combined with blood lactate meas-urement in the triage, treatment guidance and prognosis prediction of children's compound injuries.*

Methods: *From January 2023 to December 2024, a prospective, randomized, single-blind controlled trial was conducted in the emergency department of Hebei Provincial Children's Hospital (the only tertiary pediatric medical center in Hebei Province), China. A total of 546 children with combined injuries who visited the hospital were included and randomly divided into the intervention group (n=273, managed by PTS combined with dynamic monitoring of blood lactate) and the control group (n=273, managed by PTS only). The main outcome in-dicators are the timeliness of rescue (time to critical intervention) and the accuracy of prognosis prediction (predictive effectiveness of mortality and major complications). Sec-ondary outcomes included emergency department length of stay, unplanned ICU admission, and 30-day complication rate.*

Results: *The median time from admission to initiation of key interventions was significantly shorter in the intervention group compared with the control group (45 [IQR: 30-65] minutes vs. 68 [IQR: 45-95] minutes, $P < 0.001$). The area under the receiver operating characteristic curve (AUC) of the combined indicator (PTS + initial lactate) to predict 30-day mortality was 0.936 (95% CI: 0.902-0.970), which was significantly higher than PTS alone (AUC: 0.812, $P < 0.001$) or initial lactate (AUC: 0.855, $P = 0.002$). The emergency stay time, unplanned ICU admission rate and 30-day complication rate of the intervention group were significantly lower than those of the control group (all $P < 0.05$). Dynamic monitoring showed that 6-hour lactate clearance <30% was a strong independent predictor of the occurrence of multiple organ dysfunction syndrome (OR = 5.42, 95% CI: 2.88-10.21, $P < 0.001$).*

Conclusion: *The combined application of PTS and blood lactate integrates physiological status and metabolic information, which can significantly improve the accuracy of early triage of children's compound injuries, guide the implementation of rescue measures, and effectively predict prognosis through dynamic monitoring, providing a reliable basis for precise individual management.*

Keywords: Pediatric Trauma Score, Blood Lactate, Combined Injuries in Children, Prognosis, Clinical Decision-Making, Randomized Controlled Trial.

Abbreviations

The following abbreviations are used in this manuscript:

PTS	Multidisciplinary Digital Publishing Institute
IQR	Directory of open access journals
MODS	Three letter acronyms
AUC	Linear dichroism
GCS	GCS
ARDS	Acute Respiratory Distress Syndrome
AKI	Acute Kidney Injury
PRISM III	Pediatric Risk of Mortality III
CI	Confidence interval

Introduction

Child accidental injuries have become one of the leading causes of death and acquired disa-bility among children worldwide, especially in developing countries. Among various types of injuries, high-energy injuries are the main ones that pose a threat to the lives of children. According to statistics in the United States in 2004, deaths caused by trauma accounted for 59.5% of the total mortality of children under 18 years old. According to data from the Chinese Center for Disease Control and Prevention, from 2010 to 2015, the main cause of death among adolescents under the age of 19 was accidental injuries, accounting for 40%-50% of all deaths[1]. At the same time, China's child population accounts for 12. 9%, ranking second in the world, so how to reduce accidental injuries to children is an urgent problem that needs to be solved. Therefore, how to conduct early, rapid and accurate as-sessment in this critical situation, thereby optimizing treatment strategies and efficiently allocating limited medical resources, is the core challenge facing pediatric emergency de-partments[2-4].

Traditional trauma scoring systems, such as the Pediatric Trauma Score (PTS) designed specifically for children, provide clinicians with a relatively objective injury severity grading tool by quantitatively assessing children's weight, airway status, systolic blood pressure (adjusted for age), state of consciousness, wounds and fractures. Although data on each pa-rameter of the trauma score is easy to obtain, it is easily affected by various internal and external factors, thus affecting the timeliness of triage and rescue [5]. A large number of studies have confirmed that reduced PTS scores are significantly associated with increased childhood trauma mortality [6]. However, PTS mainly relies on immediate clinical mani-festations, and its sensitivity is relatively insufficient for latent shock or early cellular me-tabolism abnormalities that have not yet shown obvious physiological signs. Therefore, ref-erence of clinical manifestations and biochemical information together may be a more reli-able tool for assessing mortality risk in trauma patients. There is an urgent clinical need for objective biomarkers that can supplement insufficient PTS and reflect changes in the internal microenvironment of the body[7,8].

Blood lactate, as a key product of tissue hypoxia and anaerobic cell metabolism, increases in blood lactate levels during shock, severe tissue damage, or hypoperfusion. In the field of pediatric trauma, studies have confirmed the direct relationship between initial blood lac-tate level, lactate clearance rate and death . Especially when the blood lactate concentration is ≥5 mmol/L, the risk of death increases sharply, suggesting the need to immediately initi-ate higher-level rescue intervention.More importantly, compared with a single measurement, dynamic changes in lactate levels (such as lactate clearance) have a higher prognostic value, and their downward trend directly reflects the effectiveness of resuscitation treatment and the repayment of tissue oxygen debt [9].

In recent years, strategies that combine traditional scoring systems with biomarkers such as blood lactate have shown great potential in adult and some pediatric studies. For example, studies in the pediatric intensive care unit (PICU) have shown that the combined initial lac-tate and PRISM III score has a better predictive value for childhood trauma mortality than either single index [10]. These evidences strongly suggest that combining PTS with blood lactate measurement is expected to build a more comprehensive assessment system. To test this hypothesis, we designed and implemented this prospective randomized controlled trial to systematically evaluate the clinical significance of this combined strategy in improving the accuracy of triage, timeliness of rescue, treatment guidance value, and accuracy of prognosis prediction[11].

Materials and Methods

Research design and setting

This study was a prospective, randomized, single-blind controlled trial conducted in the emergency department of the only tertiary pediatric medical center in Hebei Province, Chi-na. The study period is from January 1, 2023 to December 31, 2024. The research protocol was reviewed and approved by the Ethics Committee of our hospital (approval number: 202301-03), and the parents or legal guardians of all participating children signed written informed consent[12].

Research objects

Inclusion criteria: (1) Age 0-14 years old; (2) Compound injuries (defined as injuries in-volving two or more anatomical parts) caused by traffic injuries (including passengers in motor vehicles, pedestrians, and bicycle/electric vehicle accidents); (3) Sent to the emer-gency department of our hospital within 24 hours after the injury.

Exclusion criteria: (1) known to have inborn metabolic diseases (such as mitochondrial disease); (2) combined with severe chronic underlying diseases (such as end-stage renal disease, severe heart failure); (3) declared dead before hospital; (4) parents refused to par-ticipate in this study[13].

Randomization and blinding

A computer-generated random number table was used to select 546 children who met the inclusion criteria as follows: 1 were randomly assigned to the intervention group or the control group. The random allocation plan was concealed in sequentially numbered, opaque, sealed envelopes. Due to the nature of the intervention, blinding of the clinicians and nurses responsible for the management of the children was not possible. However, researchers re-sponsible for outcome assessment (eg, review of medical records to identify complications, conduct of follow-up telephone calls) and statistical analysis of data were blinded to group assignment to minimize measurement bias[14].

Interventions

Control group (n = 273): Children undergo standard trauma assessment and management procedures from the time of admis-

sion. The algorithm is entirely based on the Pediatric Trauma Score (PTS). PTS is assessed and calculated immediately upon arrival by the triage nurse and the receiving physician. The PTS scoring criteria are shown in Table 1. According to the established plan of our center, advanced trauma life support procedures are initiated for children with PTS ≤ 8 points. Intervention group (n = 273): Children received a com-prehensive management program based on the combined measurement of PTS and blood lactate.

While completing the PTS assessment, complete the first blood lactate test (L0) via arterial blood collection (preferred) or venous blood collection within 10 minutes of the child's arrival in the emergency room. The decision tree of the joint management plan is shown in Figure 1. Specifically, meeting any of the following conditions will trigger the accelerated clinical pathway: ① PTS ≤ 8 points; ② Initial blood lactate ≥ 2.5 mmol/L. This path includes immediately notifying senior emergency physicians and trauma team leaders to arrive on scene, preparing resuscitation fluids and blood products in advance, and prioritizing imaging examinations. In addition, blood lactate levels were measured repeat-edly at 2 and 6 hours (L2, L6) after the initial blood collection.

The lactate clearance calcu-lation formula is: [(L0 - L2) / L0] × 100%. If the lactate clearance rate at 2 hours is < 10% or the lactate value at 6 hours is still > 2. 0 mmol/L, initiate a treatment re-evaluation pro-cess, including consideration of more in-depth volume status assessment (such as ultra-sound), adjustment of fluid resuscitation regimen, or early transfer to ICU[15].

Observation Indicators

Main outcome measures:

Timeliness of rescue: Record the time (minutes) from emergency admission to the start of key interventions. Key interventions include initiating a massive transfusion protocol, per-forming emergency surgery (eg, exploratory laparotomy, decompressive craniotomy), and performing invasive mechanical ventilation due to hemodynamic instability[16]. Prognostic prediction accuracy: Evaluate the predictive ability of different indicators (PTS, initial lactate, and the combination of the two) for 30-day mortality and major complica-tions (defined as multiple organ dysfunction syndrome MODS) in children, and compare them through the receiver operating characteristic curve (ROC curve) and the area under the curve (AUC)[17-19].

Secondary outcome measures:

1. Emergency stay time (hours).
2. Unplanned ICU admission rate (%): refers to the proportion of cases that were planned to be admitted to the general ward after initial evaluation, but needed to be transferred to the ICU due to worsening of the condition within 24 hours.
3. 30-day complication rate (%): including sepsis, acute respiratory distress syndrome (ARDS), acute kidney injury (AKI), etc.
4. 30-day all-cause mortality (%).

Table 1: Pediatric Trauma Score (PTS) System

Parameter	+2 Point	+1 Point	-1 Point
Weight(kg)	>20	10-20	<10
Airway status	Normal	Sustainable	Unable to sustain/Need intubation
Systolic blood pressure(mmHg)	>90	50-90	<50
State of consciousness	Sober	Dull/Blurred consciousness	Unconscious
Open wound	None	Slightly	Major/Penetrating injury
Fracture	None	Closure/Suspected	Openness/Multiple

Using SPSS 26.0 and R language (4.0. 2 version) for statistical analysis. Measurement data that conform to normal distribution are expressed as mean ± standard deviation, and the in-dependent samples t test is used for comparison between groups; non-normally distributed data are expressed as median (interquartile range, IQR), and Mann-Whitney U test is used for comparison between groups. Enumeration data were expressed as the number of cases (percentage), and comparisons between groups were performed using the χ^2 test or Fisher's exact test. ROC curve analysis was used to evaluate the predictive performance of each in-dicator, and the DeLong test was used to compare the AUC differences of different ROC curves.

clinical decision-making process

Evaluate PTS and initial lactate (L0) immediately after admission. If PTS ≤ 8 or L0 ≥ 2.5 mmol/L, the "accelerated path" will be triggered immediately, advanced life support will be given, a green channel will be opened for examination and treatment, and dynamic moni-toring will be performed at the same time. If PTS ≥ 8 or L0 ≤ 2.5 mmol/L, follow the normal procedure. Repeat the lactate test at 2 hours (L2) and 6 hours (L6), and calculate the 2-hour lactate clearance rate. If the 2-hour clearance rate is < 10% or L6 > 2. 0 mmol/L, the treatment needs to be re-evaluated, the treatment plan should be adjusted in real time, and early transfer to the ICU should be considered. If the 2-hour lactate clearance rate is normal, the current treatment should be continued.

Multivariate logistic regression analysis was used to explore the independent risk factors affecting prognosis, and the odds ratio (OR) and its 95% confidence interval (CI) were cal-culated. All statistical analyzes were two-sided tests, with P < 0. 05 means the difference is statistically significant.

Result

Comparison of baseline data

During the study period, a total of 580 children were screened, and finally 546 cases were included in the analysis, including 273 cases in the intervention group and the control group. There were no statistically significant differences between the two groups of children in terms of age, gender, injury mechanism distribution, PTS score on admission, Glasgow Coma Scale (GCS) and other baseline data (P > 0. 05), indicating that the randomized groups are well balanced (Table 2).

Table 2: Comparison of baseline data between the two groups of children

Attribute	Intervention group(n=273)	Control group(n=273)	Statistic	P value
Age (year), M (IQR)	6.5 (3.0-10.0)	7.0 (3.5-10.5)	Z = -0.891	0.373
Male, n (%)	172 (63.0%)	165 (60.4%)	χ^2 = 0.402	0.526
Damage mechanism, n (%)			χ^2 = 1.205	0.752
Pedestrian collision	145 (53.1%)	138 (50.5%)		
Passengers in the c	98 (35.9%)	105 (38.5%)		
Bicycle/electric vehicle	30 (11.0%)	30 (11.0%)		
On admission PTS, M (IQR)	7 (5-9)	7 (5-9)	Z = -0.456	0.648
On admission GCS, M (IQR)	13 (9-15)	14 (10-15)	Z = -1.123	0.261
Initial lactate (mmol/L), M (IQR)	3.8 (2.5-5.5)	3.6 (2.4-5.2)	Z = -1.104	0.270

The median time from admission to key intervention was significantly shorter in the inter-vention group than in the control group (45 minutes [IQR: 30-65] vs. 68 minutes [IQR:45-95], Z = -5.892, P < 0. 001.

Accuracy of prognostic prediction

By the end of the study, a total of 28 children (5.1%) had died. When comparing PTS with initial lactate alone, the difference was not statistically significant (P = 0.215). In terms of predicting the occurrence of MODS, the joint indicator also showed the highest predictive value (AUC: 0. 915).

Table 3: ROC curve analysis results of each indicator predicting 30-day mortality

Predictive indicators	AUC	95% CI	Best Truncation Value	Sensitivity	Specificity	P value (vs. joint indicator)
PTS	0.812	0.750-0.874	≤ 5	0.821	0.734	< 0.001
Initial lactate	0.855	0.798-0.912	≥ 4.5 mmol/L	0.786	0.802	0.002
Joint indicator	0.936	0.902-0.970	-	0.893	0.857	-

Secondary outcome measures

The intervention group showed significant advantages in all secondary outcome indicators (Table 4). The intervention group had a shorter median length of stay in the emergency de-partment, a significantly lower rate of unplanned ICU admission and any complication within 30 days than the control group.

3. 4. In-depth analysis of the relationship between dynamic monitoring of lactate and prog-nosis We conducted an in-depth analysis of the data from the intervention group, focusing on the value of lactate clearance. Children in the intervention group were divided into high clear-ance group (≥30%) and low clearance group (<30%) according to whether the 6-hour lactate clearance rate reached 30%. Multivariate logistic regression analysis (adjusted for age, gender, initial PTS and initial lactate) showed that 6-hour lactate clearance <30% was a strong independent predictor of MODS in children (adjusted OR = 5.42, 95% CI: 2.88-10.21, P < 0. 001.

Table 4: Comparison of secondary outcome indicators between the two groups of children

Indicator	Intervention group(n=273)	Control group (n=273)	Statistic	P value
Emergency stay time (hours), M (IQR)	4.5 (3.0-6.5)	5.8 (4.0-8.0)	Z = -4.123	< 0.001
Unplanned ICU stay, n (%)	15 (5.5%)	32 (11.7%)	χ^2 = 6.714	0.010
30-day complications, n (%)	45 (16.5%)	68 (24.9%)	χ^2 = 6.125	0.013
Sepsis	18 (6.6%)	25 (9.2%)		
ARDS	12 (4.4%)	20 (7.3%)		
AKI	15 (5.5%)	23 (8.4%)		
30-day mortality rate, n (%)	11 (4.0%)	17 (6.2%)	χ^2 = 1.363	0.243

Discussion

This study confirms that combining the Pediatric Trauma Score (PTS) with blood lactate measurement has a significant synergistic effect in the treatment and management of chil-dren's combined injuries. This joint strategy is an effective plan that can directly guide clinical actions and optimize the treatment

process. First, this study found that this joint strategy greatly improved the timeliness of rescue. Time from admission to critical intervention was significantly reduced in the intervention group 35% (45 minutes vs. 68 minutes).

This is due to the clear and objective trigger conditions set in the combination protocol (PTS ≤ 8 or lactate ≥ 2.5 mmol/L). Because when the blood lactate concentration exceeds 2.0 mmol/L, it is difficult for the liver to clear it, and if it exceeds 4. The mortality rate of children increased significantly at 0 mmol/L [12]. Some children may have acceptable PTS scores but already have hyperlactatemia caused by tissue hypoperfusion, which is called "occult shock." Using PTS alone, the risks of such children may be underes-timated and intervention delayed. Our joint solution can identify these children early and allow them to enter the green treatment channel in advance. This is a good application of the precision medicine concept in the field of emergency trauma [13].

Secondly, in terms of prognostic prediction accuracy, the combined index shows its better advantages. Its AUC for predicting mortality is as high as 0. 936, which is an excellent pre-diction level and significantly better than any single indicator. This verifies our core hy-pothesis: PTS assesses injury from a macro-physiological level, while blood lactate reflects the degree of criticality within the body from a micro-metabolic level. The combination of the two provides a more comprehensive assessment strategy, allowing clinicians to identify earlier and more accurately high-risk children who appear to be stable but are actually critical.

Furthermore, our analysis of dynamic monitoring of lactate revealed its enormous value beyond initial values. A 6-hour lactate clearance <30% was identified as a strong independent risk factor for MODS (OR > 5). At the same time, previous studies have suggested that there is a positive correlation between severe hyperlactatemia, lactate clearance and mortality in critically ill patients [16]. This finding is highly consistent with the concept of “lac-tate-guided resuscitation” in critical care medicine [17]. Initial lactate levels reflect the se-verity of tissue damage, while lactate clearance dynamically reveals the body's ability to respond to treatment. Persistent hyperlactatemia is a strong warning sign that initial resus-citation is inadequate or that persistent bleeding or ischemia exists, requiring immediate re-evaluation of treatment strategies. This study successfully integrates this concept into the early management of pediatric trauma and demonstrates its effectiveness through data.

In terms of clinical outcomes, the combined management strategy brought about compre-hensive improvements. The shorter emergency stay time and lower unplanned ICU admission rate in the intervention group illustrate that this strategy improves the accuracy of initial triage and treatment and avoids subsequent confusion and resource loss caused by inaccurate disease judgment,Source wasted. At the same time, the significantly lower 30-day compli-cation rate may be related to earlier and more effective initial resuscitation, as well as timely treatment adjustments based on lactate trends, thereby preventing further deterioration of organ function. This study also has some limitations. The single-center design may limit the generalizability of the results, requiring external validation in hospitals at different levels and in different regions. Second, although blinded assessments were implemented, the treatment team was not blinded, potentially introducing potential performance bias. In addition, we mainly used arterial/venous blood to detect lactate. In the future, we can explore the feasibility of using bedside fingertip blood lactate detectors in this solution to further improve convenience.

Conclusion

The conclusions of this study are as follows: In the clinical treatment of children with com-pound injuries, using a comprehensive management strategy of pediatric trauma score (PTS) combined with blood lactate measurement can significantly shorten rescue response time and improve treatment efficiency compared to using PTS alone. Greatly improve the accuracy of early prediction of death and serious complications. By dynamically monitoring lactate clearance, we can effectively evaluate treatment response, guide the adjustment of resusci-tation strategies, and improve patient prognosis.

Therefore, we strongly recommend the combined application of PTS and blood lactate (especially dynamic monitoring) as a stand-ardized assessment and management process for children with complex injuries in pediatric trauma centers and qualified emergency departments, in order to achieve more precise indi-vidualized treatment and ultimately reduce the mortality and disability rates of children.

Future prospects: Follow-up research can focus on developing machine learning prediction models that integrate PTS, lactate, and even other new biomarkers (such as procalcitonin), that is, artificial intelligence technology. Because artificial intelligence technology has unique advantages in identifying data associations and computing speed, it has become a potential solution to many clinical problems [15]. In order to achieve earlier risk warning. At the same time, it is also important to verify the applicability of this combined strategy in a broader pediatric trauma population (e.g., fall injuries, burns).

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