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Predictors of polytrauma outcomes in the early period in children

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BACKGROUND: The problem of anti-shock measures and stabilization of the general condition of the affected children with polytrauma at the stage of intensive care is an extremely urgent issue in pediatric traumatology. Various aspects, such as determining the most sensitive prognostic scale for assessing the severity of polytrauma, clinical and laboratory predictors of changes in the vector of development of the course of traumatic disease in the direction of thanatogenic orientation, remain actively discussed among clinicians.

AIM: The aim of the study is to analyse the dynamics of changes in the indicators of internal homeostasis in children with polytrauma, indicating a favorable or thanatogenic direction of the course of the traumatic disease.

MATERIALS AND METHODS: A retrospective analysis of the medical records of 49 patients diagnosed with polytrauma was performed. All patients were divided into two groups: the survivors' group comprised 41 patients, and the deceased group consisted of 8 patients.

All patients were examined for total blood count (Er, Tr, Ht, Hb, le, ESR), acid-base state (pH, SBC, BE), blood biochemical parameters (creatinine, urea, ALT, AST, K, Na, Ca), and C-reactive protein. The tests were performed daily during the first 10 days of the acute phase of the injury. The severity of the injury was determined by the NISS and pediatric trauma score scales, and in the case of a traumatic brain injury, the Glasgow coma scale was used.

A logistic step-by-step regression analysis was performed to identify predictors of polytrauma outcomes. The statical significance was considered at $p < 0.05$.

RESULTS: The step-by-step logistic regression revealed significant predictors that determined the unfavorable outcome of polytrauma (death), already on the second day. They were the NISS score, the level of CRP, Hb, Er, Na, and creatinine. At the same time, the statistical significance in the dynamics of changes in red blood parameters (Er, Hb), blood ionic composition (Na, K), humoral activity (Le, ESR, CRP) remained up to 10 days, i.e., during the period of possible complications of the traumatic disease. Our data offered the possibility to derive an equation for calculating the risk of failure of compensatory mechanisms in polytrauma.

CONCLUSIONS: The course of traumatic disease in children with polytrauma is characterized by morpho-functional changes in many organ systems. Predictors of failure of compensatory-adaptive mechanisms in response to polytrauma can be determined already in the early post-shock period.

Keywords: polytrauma; children; clinical and laboratory parameters.

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Предикторы исходов политравмы в ранний период травматической болезни у детей

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Обоснование. Проблема противошоковых мероприятий и стабилизации общего состояние пострадавших детей с политравмой на этапе интенсивной терапии является крайне актуальной в детской травматологии. Многие аспекты, такие как определение наиболее чувствительной прогностической шкалы оценки тяжести политравмы, клинико-лабораторных предикторов изменения вектора развития течения травматической болезни в сторону танатогенной направленности, активно обсуждаются в среде клиницистов.

Цель — анализ динамики изменений показателей внутреннего гомеостаза у детей с политравмой, свидетельствующих о благоприятной или танатогенной направленности течения травматической болезни.

Материалы и методы. Выполнен ретроспективный анализ историй болезни 49 пациентов с диагнозом «политравма». Все пострадавшие разделены на две группы: 41 пациент составил группу выживших, 8 — группу умерших.

Всем пациентам исследовали показатели общего анализа крови (эритроциты, тромбоциты, гематокрит, гемоглобин, лейкоциты, скорость оседания эритроцитов), кислотно-основного состояния (pH, SBC, BE), биохимические показатели крови (креатинин, мочевина, аланинаминотрансфераза, аспартатаминотрансфераза, калий, натрий, кальций), белка острой фазы (С-реактивный белок). Анализы выполняли ежедневно в течение первых 10 сут острого периода травмы. Для определения тяжести травмы использовали шкалы NISS, pediatric trauma score, в случае наличия черепно-мозговой травмы — шкалу комы Глазго.

Для выявления предикторов исходов политравмы была проведена логистическая пошаговая регрессия. Значимость достигалась при $p < 0{,}05$.

Результаты. Пошаговая логистическая регрессия выявила значимые предикторы, определяющие неблагоприятный исход политравмы (смерть), уже на вторые сутки. Ими оказались оценка по шкале NISS, уровень С-реактивного белка, гемоглобина, эритроцитов, натрия, креатинина. В то же время статистическая значимость в динамике изменений в показателях красной крови (эритроциты, гемоглобин), ионного состава крови (натрий, калий), гуморальной активности (лейкоциты, скорость оседания эритроцитов, С-реактивный белок) сохранялась до 10 сут, то есть в период наиболее возможных осложнений травматической болезни. В результате удалось вывести уравнение для расчета риска срыва компенсаторных механизмов при политравме.

Заключение. Течение травматической болезни у детей с политравмой характеризуется морфо-функциональными изменениями во многих системах органов. Предикторы срыва компенсаторно-адаптивных механизмов в ответ на политравму могут быть определены уже в ранний послешоковый период.

Ключевые слова: политравма; дети; клинико-лабораторные показатели.

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ЭКО•ВЕКТОР

BACKGROUND

The incidence rate of severe multiple and concomitant injuries in children remains high [1]. The characteristics of severe mechanical trauma with the likelihood of re-injury to the brain and high risks of death made it necessary to focus a separate nosological concept, i.e., polytrauma, with mortality rates ranging from 5% to 15% [2]. The unstable general condition of patients determined the need for the introduction of specialized algorithms for diagnostics and medical care.

Major changes in the coagulation system, acid–base balance, electrolyte composition of the blood, metabolic and immune disorders due to primary trauma, and acute blood loss entail the development of pathophysiological processes, which largely determine the essence of traumatic injury. Acute disorders of vital functions and early manifestations are the most critical periods [3].

There are many unsolved problems in predicting the outcomes of polytrauma, including the determination of the most effective prognostic scale [4]. Many variants of prognostic scales have been proposed in establishing the severity of primary mechanical injury and condition of the patient. Multistep scales are recommended for calculating the risk of death. However, the optimal method for predicting the course of a traumatic injury for clinical use is still not established. Attempts to develop a unified and universal prognostic scale are unsuccessful, and several authors consider it necessary not to develop new scales but to improve the existing ones [4].

In real conditions, the time frames for various periods of traumatic injury may be unclear and not characterized by a pronounced typical clinical picture, which makes it difficult to understand the functional capabilities of a child with traumatic injury. The instability of indicators of internal homeostasis dictates the need for monitoring of vital functions and constant analysis of changes in clinical and laboratory indicators, which sometimes, due to numerous factors, is not always possible. Thus, there is a need for a clear understanding of the thanatogenic or reconvalescent orientation of traumatic injury in each case, based on the identification and integral analysis of the most sensitive clinical and laboratory predictors of changes in the early period of traumatic injury. Several studies have investigated diagnostic predictors of the unfavorable course of a traumatic injury in adults [5–7].

Some authors are guided by indirect signs of a more favorable course of a traumatic injury in children, such as a decrease in the number of bed-days [8, 9]. In recent years, in pediatric practice, the search for objective clinical and diagnostic criteria that indicate a convalescent or thanatogenic direction of the course of a traumatic injury gained research interest [10]. With an objective assessment of the patient's condition, the attending physician can provide intensive care to a child with traumatic injury. In this regard, a promising direction for the early diagnosis of complications of polytrauma is the search for predictors of an unfavorable course of the acute period [11].

This study aimed to analyze the dynamics in the indices of internal homeostasis in children with polytrauma, indicating a favorable or thanatogenic direction of the course of traumatic injury.

MATERIALS AND METHODS

This study retrospectively analyzed case histories of 49 patients with a diagnosis of polytrauma who were treated in the intensive care unit of Kuzbass Regional Children's Clinical Hospital (Kemerovo) in the period from 2015 to 2020.

The diagnosis of polytrauma was made when the New Injury Severity Score (NISS) value was >16 points. The patients' age ranged from 1 to 16 years, with an average age of 12 years. All patients were divided into two groups depending on the outcomes of the polytrauma: 41 patients made up the survivor group and eight patients comprised the deceased group in which fatal outcomes occurred >10 days after the polytrauma. The exclusion criterion was the death of the patient within 10 days from the occurrence of injury.

All patients underwent measurements of routine blood count (erythrocytes, platelets, hematocrit, hemoglobin, leukocytes, and erythrocyte sedimentation rate), acid–base analysis (pH, standard bicarbonate, base excess), blood biochemical parameters (creatinine, urea, alanine aminotransferase, aspartate aminotransferase, and calcium), and C-reactive protein (CRP, acute-phase protein). Analyses were performed in all patients daily during the first 10 days from the moment of injury. On admission to the intensive care unit, all patients were assessed according to the NISS scale to determine the severity of the injury. The pediatric trauma scale was also used. In case of a traumatic brain injury (TBI), the Glasgow coma scale was applied.

The results were processed using the Statistica for Windows version 10.0 (StatSoft Inc., USA) and MedCalc version 17.5.3 (MedCalc Software, Belgium) according to the rules of variation statistics.

To identify predictors of polytrauma outcomes, multiple logistic stepwise regression and receiver operating characteristics curve (ROC) analysis were performed. Multiple logistic regression is a statistical classification method using Fisher's linear discriminant. In this study, we used a variant of stepwise regression, in which the space of values of the training sample was divided by a linear border into two areas corresponding to points: 1 point, death 10 days from the moment of injury; 0 points, recovery and discharge after polytrauma. This division makes it possible to identify the factors associated with the thanatogenic effect of polytrauma.

Based on logistic function, the risks of a thanatogenic outcome after polytrauma were calculated. Predictors were searched for according to clinical and laboratory parameters from day 1 to day 10 after polytrauma.

To assess the significance of the proposed equations in predicting the risk of a thanatogenic outcome after polytrauma, ROC analysis was performed with the calculation of the following parameters: area under the curve (characterizes the diagnostic value of the indicator; 0.9–1.0, excellent; 0.8–0.9, very good; 0.7–0.8, good; 0.6–0.7, average; ≤0.6, unsatisfactory), sensitivity (*Se*) and specificity (*Sp*) of the factor, and critical value (cutoff point) indicators.

Quantitative data were presented as median (*Me*) and 25th and 75th percentiles (Q_{25} and Q_{75}). Values of metric indicators in unrelated samples were compared using the nonparametric Mann–Whitney test. The level of significance was taken at $p < 0.05$, which corresponds to biomedical studies [12].

RESULTS

Treatment of patients with polytrauma presents many difficulties and questions, which require patient-specific solution. The course of the traumatic injury in such patients is largely determined by the nature of the leading injury. The structure of the leading injury in patients divided in two groups according to the classification of V.A. Sokolov is presented in Table 1.

The study showed that the most common cause of death was TBI, which accounts for 75% of the cases in the deceased group. In patients with fatal outcomes, abdominal trauma was the most severe trauma and combined with two or more leading injuries in 12.5% of cases each. Moreover, the survivor group was characterized by severe injuries: TBI (36.7%), abdominal trauma (21.9%), and damage to ≥2 areas (21.9%) were predominant traumas. Comparative analysis showed that the groups differed significantly only the incidence of TBI.

A nonparametric analysis of the Glasgow coma scale score reflected significant differences between groups with a predominance of a more severe neurological status in the deceased group (Glasgow coma scale: 3.85, 2.82, and 4.89 in the deceased group, and 7.43, 3.81, and 11.07 in the survivor group, $p < 0.05$). In several patients with TBI as the primary injury, including two patients in the deceased group, in the presence of minor injuries in other organ systems, the NISS value did not exceed 25 points. Thus, in such patients, the Glasgow coma scale is preferred when determining the severity of injury, which reflects the severe neurological status on admission to the intensive care unit.

Stepwise logistic regression revealed significant clinical and laboratory predictors of an unfavorable outcome of polytrauma on day 2 after injury (Table 2). The severity of primary mechanical trauma, acute blood loss, and subsequent disturbances in internal homeostasis during the

Table 1. Structure of polytrauma in children according to the classification of V.A. Sokolova

	Combined with brain injury (abs./%)	Combined spinal cord injury (abs./%)	Combined chest injury (abs./%)	Combined abdominal injury (abs./%)	Combined injury of the musculoskeletal system (abs./%)	Combined injury of 2 areas or more (abs./%)
Survivor group	15/36.7	1/2.4	2/4.8	9/21.9	5/12.3	9/21.9
Deceased group	6/75	–	–	1/12.5	–	1/12.5
Significance of differences (*p*)	<0.05*			>0.05		>0.05

* significant difference in parameters.

Table 2. Logistic regression (step-by-step option) for assessing the risk of an unfavorable outcome of polytrauma (patient death) according to clinical and laboratory parameters determined on day 2 after injury

Predictors	β	Std. err. of β	B	Std. err. of B	*t* (8)	*p*
Free term of logistic regression			–2.924	0.758	–3.858	0.001
Sodium on day 2, X_1	0.399	0.138	0.016	0.006	2.893	0.009
NISS, X_2	0.441	0.130	0.014	0.004	3.398	0.003
C-reactive protein on day 2, X_3	–0.308	0.129	–0.003	0.001	–2.391	0.027
Hemoglobin on day 2, X_4	–1.472	0.485	–0.035	0.012	–3.036	0.007
Creatinine on day 2, X_5	0.845	0.327	0.010	0.004	2.584	0.018
Erythrocytes on day 2, X_6	1.117	0.484	0.725	0.314	2.306	0.033

Note. X_1–X_6, significant predictors (variables) for the logistic function equation; β, regression coefficient β; Std. err. of β, β-coefficient error; B, regression coefficient B; Std. err. of B, B-coefficient error; *t* (8), Student's *t* distribution.

first 2 days from the occurrence of injury were established as the most significant manifestations, which correspond to the period of shock and relative stabilization.

As shown in Table 2, parameters that have positive and negative effects on an unfavorable outcome after polytrauma were determined. β-coefficients reflect the relative influence of the predictor on the dependent variable, and B-coefficients indicate the predictive value of the predictor.

These predictors were the NISS value and levels of CRP, hemoglobin, erythrocytes, sodium, and creatinine on day 2 after injury. As a result of the data analysis, it was possible to derive an equation for calculating the risk of breakdown of compensatory mechanism in polytrauma, based on the integral assessment of the presented indicators:

$$Y = (\exp Z / (1 + \exp Z)) \cdot 100,$$

$$Z = (-2.924 + 0.016X_1 + 0.014X_2 - 0.003X_3 - 0.035X_4 + + 0.01X_5 + 0.725X_6),$$

where X_1 is the concentration of Na^+ ions in the patient's blood serum on day 2 after polytrauma, mmol/l; X_2, severity of polytrauma on the NISS scale on admission, points; X_3, CRP level in the patient's blood serum on day 2 after polytrauma, mg/l; X_4, hemoglobin level in the patient's blood serum on day 2 after polytrauma, g/l; X_5, creatinine level in the patient's blood serum on day 2 after polytrauma, μmol/l; X_6, peripheral erythrocyte count on day 2 after polytrauma, 10^{12}/l.

ROC analysis was performed to identify the sensitivity and specificity of the equation for calculating the risk of the thanatogenic effect after polytrauma (Table 3, Figure).

In Figure, the specificity (ability to determine truly positive results) of the resulting equation was 85.71%, and the sensitivity (ability to determine truly negative results) was 100%. These conditions were met with the criterion for distinguishing between positive and negative results (associative criterion) equal to 42.15%. The Youden index (*J*) which determines the overall efficiency of the equation [specificity *J* (in fractions) + sensitivity (in fractions) – 1], tended to unity (0.86), which confirms the high efficiency of the resulting formula for calculating the risk. Thus, the coefficient obtained using the presented equation, over 42.15%, corresponds to a high risk of death. Higher results serve as a prognostic criterion for an unfavorable outcome of a traumatic injury. The high sensitivity and specificity of the proposed equation make it possible to determine the predictors of the development of traumatic injury and timely correction of the direction of intensive care, based on dynamic changes in one or another laboratory indicator of internal homeostasis.

When calculating risks using the proposed equation, the most significant indicators were used according to logistic regression data. Multivariate logistic regression reflected the sensitivity in predicting the course of traumatic injury

Table 3. Main parameters of the ROC analysis for the equation for assessing the risk of thanatogenic effect in polytrauma developed on the basis of logistic regression

Parameter	Value
Youden index, *J*	0.8571
Associated criterion	>42.15411528
Sensitivity	85.71
Specificity	100.00

using the NISS value. While the Glasgow coma scale is a tool for diagnosing a specific cohort of patients with TBI as the leading injury and, like the pediatric trauma score, it did not demonstrate significance in determining the course of traumatic injury. The study showed that the NISS value has a directly proportional relationship in calculating the risk of mortality, and the B-coefficient displayed a high predictive value of the predictor in the presented equation. Moreover, in the nonparametric comparison of indicators on the NISS scale in the survivor group and deceased groups, no significant differences were found, although the mean values were higher in the deceased group (NISS, 53.85, 26.47, and 81.23 for the deceased group; 36.01, 22.54, and 49.45 for the survivor group, $p > 0.05$).

Creatinine level is a significant criterion in predicting the course of traumatic injury in the early post-shock period. When calculating the risks of an unfavorable outcome, this predictor displayed a positive relationship and high sensitivity. High creatinine levels significantly increase the risk of death. It is a metabolite of protein breakdown

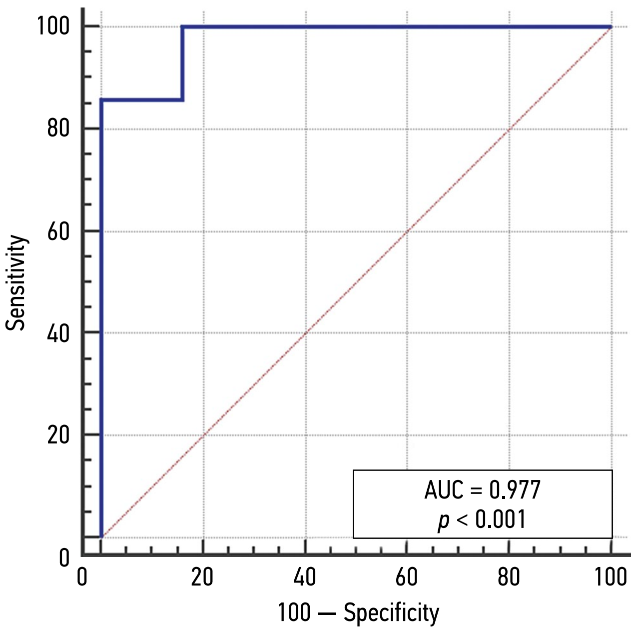

Figure. ROC analysis and determination of the specificity and sensitivity when calculating the risk of an unfavorable outcome of polytrauma (death). The criterion for distinguishing between favorable and unfavorable outcomes (associative criterion) is determined by a value greater than 42.15%

in muscles, and a change in its concentration in the blood indicates not only a kidney malfunction but also necrosis and massive muscle damage. The increasing level of creatinine in the blood of patients with polytrauma in the first 2 days indicates gross morphological changes caused by severe mechanical trauma. The significance of the creatinine concentration in conjunction with the assessment of the severity of the injury based on the NISS scale indicates a direct relationship between the volume of injuries and risk of death in children.

An important link in determining the course of a traumatic injury is the degree of primary blood loss and the possibility of correcting it with replacement therapy, and its effect on ongoing bleeding condition cannot always be obtained in the shortest possible time. A critical drop in the red blood cell count due to massive blood loss leads to a decrease in oxygenation, which, with existing tissue hypoperfusion, contributes to the emergence and progression of oxygen starvation, activation of the anaerobic pathway of glycolysis, and metabolic acidosis. Erythrocyte count and hemoglobin level were significantly sensitive in the stepwise logistic regression. The listed predictors exerted a negative effect on the outcomes of polytrauma and had high diagnostic significance. A low red blood cell count significantly increases the risk of death.

In the presence of a decrease in oxygen delivery to the tissues during the initial stage of the failure of compensatory mechanisms in response to polytrauma, a change in the ionic composition of the blood occurs. The level of sodium in the blood is the most sensitive predictor of the unfavorable course of polytrauma in the first 2 days, which characterizes the osmotic pressure of the blood and regulates the function of the membrane potential of the cell. In a critical condition associated with massive blood loss, impaired electrolyte composition of the blood leads to the movement of sodium and hydrogen into the cell, edema, and cell death through apoptosis.

The membrane potential of the cell determines the course of all pathological processes in patients with polytrauma. Thus, the level of sodium ions in the blood had a direct effect on the risks of having an unfavorable course of traumatic injury. Moreover, the result of the logistic regression analysis displayed a β-coefficient of 0.138, which indicates the high sensitivity of the predictor. Accordingly, the high rates of this predictor significantly increase risk of death. When determining the volume of infusion therapy, dynamic changes in the ionic composition of the blood should be monitored.

From the first day after sustaining a severe mechanical injury, the patient is at risk of a systemic inflammatory response syndrome (SIRS), which can be predicted in the early period of polytrauma based on the CRP level. According to several authors, this indicator is one of the most sensitive predictors of SIRS development [13]. The pathophysiological basis of SIRS in polytrauma is massive mechanical damage, release of endotoxins, and global tissue perfusion deficiency, which can be reflected in the indicators of humoral activity, acute-phase proteins, and immune indicators. Multivariate logistic regression analysis revealed the high predictive value of CRP level and the direct effect of this indicator on the risks of thanatogenic orientation. A high CRP level on day 2 after polytrauma confirms the unfavorable development of the traumatic injury.

DISCUSSION

The pathophysiological mechanisms of the course of a traumatic injury in children with polytrauma largely vary and are determined by the characteristic morphofunctional response of the patient to the action of an external damaging factor. The surgical and resuscitation team should identify patterns of disintegration and disruption of the compensatory capabilities of the child; with this, it is possible to reasonably determine the volume and direction of intensive therapy, which is a prerequisite for survival. Moreover, a shift in one clinical and laboratory parameter cannot be regarded as a reliable predictor of the failure of compensatory mechanisms, but an integral multivariate assessment of changes in internal homeostasis should be considered.

This study, using several indicators analyzed during the first 10 days after a polytrauma, revealed that predictors of an unfavorable outcome can be identified in as early as day 2 after the injury. These predictors were indicators reflecting homeostasis (CRP, hemoglobin, erythrocyte, sodium, and creatinine levels) and data obtained on the NISS scale assessed immediately after admission to the intensive care unit. Since the prediction of the outcome of polytrauma falls on day 2, making a decision on the correction of intensive therapy is possible.

The ISS scale and its modification (NISS) are two of the most frequently used tools in determining the severity of a primary mechanical injury [14]. Among the main pathogenetic factors affecting the possibility of compensatory mechanism failure are the volume of mechanical damage and intensity of nociceptive impulses. The use of the NISS scale in predicting the outcomes of polytrauma indicates the objectivity of ranking the severity of injury and the possibility, in most cases, of the gradation of morphological disorders due to interaction with a traumatic agent based on the NISS value. In addition, the NISS scale can be used in a wide range of patients.

Along with the identification of the predictive sensitivity according to logistic regression data, no significant differences were found in the nonparametric comparison of the NISS values. The mean values indicated substantial damage in the deceased group, but were not significant.

In addition, findings emphasize the need for an integral multivariate assessment of the general condition of the patients and the impossibility of judging the risks of death based on only one criterion.

Nevertheless, several difficulties are reported in predicting the risks of death and deciding on the possible amount of surgical care based on the NISS value, especially in children. A notable drawback of the NISS scale is the underestimation of the severity of TBI, which is characterized by the most severe course of traumatic injury [15]. In this case, the adaptive mechanisms aimed at centralizing blood circulation during the shock period may be poorly expressed, which greatly complicates the management of patients. In patients with TBI and minor injuries in other organ systems, the NISS value does not represent a prognostically important parameter, so the Glasgow coma scale should be preferred. This study showed that TBI was the most common cause of death in children. The degree of neurological deficit, as measured by the Glasgow coma scale, correlates with the overall severity of the condition.

The acute period of polytrauma is associated with significant blood loss and risk of developing hypovolemic shock. Changes in the gas composition of the blood and decreased oxygenation and tissue hypoperfusion are the leading signs in the pathogenesis of further development of a life-threatening condition [16]. The development of post-hemorrhagic anemia contributes to the formation of the "death triad" – hypothermia, coagulopathy, and metabolic acidosis [17]. The study showed the significance of a decrease in the oxygen-carrying capacity of the blood, as reflected in a reduced level of erythrocytes and hemoglobin, in determining the predictors of the development of traumatic injury during the period of relative stabilization (up to 2 days), which emphasizes the extreme importance of successful substitution therapy in children with polytrauma.

Along with acute anemia, a decisive role in the thanatogenic direction of the development of a traumatic injury is based on impaired renal function during the period of shock and relative stabilization, expressed in a high level of creatinine in the deceased group. Thus, the high sensitivity level in the first 2 days indicates the relationship between the increase in mortality and development of acute renal failure. Moreover, an increase in creatinine concentration is associated with massive damage to muscle fibers due to trauma, which, along with a high NISS value in the multivariate analysis, confirms the relationship between the degree of traumatic injury and the risk of an unfavorable outcome [18].

An important element of compensation is the maintenance of the osmotic gradient between the intravascular and interstitial fluid, which is achieved by matching the concentration of the electrolyte composition of the blood. This study showed that the level of sodium in the blood is the most sensitive indicator in the first 2 days. The entry of sodium into the cell and, as a consequence, a decrease in serum concentration cause a change in osmotic pressure, which ultimately leads to cell membrane destruction and cell lysis in all organ systems. This condition triggers the development of multiple organ dysfunctions, results in multiple organ failure and, in the absence of timely correction, leads to death [11].

One of the most controversial issues is the development of an acute inflammatory response to severe mechanical trauma. An important predictor of an unfavorable outcome of polytrauma in children is the level of CRP in the early post-traumatic period and stress-associated molecules (DAMP), including bioactive lysophospholipids and fatty acids formed upon damage to cell membranes [19]. These patterns are present in several cases of polytrauma in children. The main cascade of the immunopathological reactions triggered by the PRR–PAMP/DAMP complexes, where PRR is CRP, is associated with the activation of complement components, arachidonic acid metabolism and synthesis of membrane mediators of inflammation, complement-associated intravascular coagulation, and endothelial damage [20]. These immunopathological reactions can be fatal. The suppression of immune inflammation in children with polytrauma and high CRP levels on day 2 are the most significant components in the treatment of these patients.

Thus, determining predictors of the development of a traumatic injury from the standpoint of assessing changes not in a single indicator of internal homeostasis but in several indicators is recommended. The proposed equation for calculating the risks of an unfavorable course of a traumatic injury allows us to more objectively judge the course of a traumatic injury. A clinical example of the development of a traumatic injury in two patients is shown below:

Patient S. was admitted to the intensive care unit and anesthesiology with a diagnosis of "polytrauma, catatrauma, closed craniocerebral injury, severe brain contusion; blunt abdominal trauma: rupture of the liver, partial rupture of the gallbladder, contusion, subserous hematomas of the stomach, rupture of the upper horizontal branch of the duodenum, contusion, subserous hematomas of the transverse colon, contusion of the pancreas; intra-abdominal bleeding; contusion of the kidneys, massive retroperitoneal hematomas; contusion of the lungs; laceration of the left lateral surface of the chest, scalped wound of the frontal region on the left." The NISS value of the patient was 43 points, and the parameters on day 2 were as follows: sodium, 139 mmol/l; CRP, 32.9 mg/l; hemoglobin, 99 g/l; creatinine, 90.2 μmol/l; erythrocytes, 3.37×10^{12}/l. The calculation according to the above equation showed a mortality risk of 42.1%, which indicates a low risk. With intensive therapy, achieving stabilization of the patient's condition is possible, the treatment outcome was satisfactory, and the patient survived.

Patient M. was admitted to the intensive care unit with a diagnosis of "polytrauma; road traffic injury; severe brain injury; massive subarachnoid hemorrhage; multiple fractures of the cranial vault; traumatic pulmonitis; closed fracture of the femur with displacement of bone fragments." The NISS value was 34 points, and indicators of internal homeostasis on day 2 were as follows: sodium, 155 mmol/L; CRP, 28.1 mg/L; hemoglobin, 68 g/L; creatinine, 61.8 μmol/L; erythrocytes, 2.36×10^{12}/l. The mortality risk was 47.4%, which corresponds to a high mortality risk. The patient, despite medical measures, died on day 12 after polytrauma. This case shows that the second patient had more favorable criteria for polytrauma according to certain indicators, in particular, a smaller amount of damage, which was reflected in a lower NISS value than the score of the first patient. However, the overall integral coefficient of the multivariate analysis according to the presented indicators of internal homeostasis on day 2 of polytrauma indicated a more severe course of a traumatic injury.

The study confirms the need for an integral and multivariate assessment of the patient's clinical and laboratory parameters, when deciding on the algorithm for surgical care and in calculating high mortality risks using the proposed equation, and to initially perform minimally invasive surgical interventions only for vital indications. Final surgical interventions in such patients should be postponed until the hemodynamic parameters and internal homeostasis indicators stabilize, which corresponds to the principles of damage control.

The question of determining the most sensitive predictors of a shift in the development toward thanatogenic orientation from multivariate monitoring of vital functions in victims is largely confirmed. In several cases, noticeable criteria for an unfavorable course of a traumatic injury, such as the amount of damage and degree of blood loss, do not always become unambiguous predictors of a thanatogenic orientation. It is more expedient to predict the risks of death on the basis of an integrated assessment of several clinical and laboratory factors. A number of the most sensitive indicators of homeostasis at the early stages of polytrauma may indicate a further breakdown of compensatory–adaptive mechanisms. In some cases, correction of these indicators can increase the chances of recovery. The calculation of mortality risks according to the proposed equation makes it possible to single out predictors of the development of traumatic injury in an unfavorable direction based on routine clinical and laboratory parameters.

CONCLUSION

The course of traumatic injury in children with polytrauma is characterized by morphofunctional changes in many organ systems. Predictors of each compensatory–adaptive mechanism in response to polytrauma can be determined in the early post-shock period. The results of this study suggest that it was possible to derive an equation for calculating the risks of failure of adaptive mechanisms based on red blood indicators, humoral activity, and electrolyte components in the blood. Calculations according to the proposed equation make it possible to correct intensive care, thus stabilize the condition of the patients, and change the course of the development of a traumatic injury.

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Author contributions. *O.N. Shabaldin* — research concept and design, data collection and analysis, literature analysis, and writing of all sections of the article. *S.I. Golovkin* — processing of the materials and writing all sections of the article. *A.V. Shabaldin* — statistical processing of the materials and staged editing of the article.

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