

Prediction of Fatal Outcomes in Patients With Severe Burns With the Use of Logistic Regression Methods

Oleg O. Zavorotnii, Evgeniy V. Zinoviev, Denis V. Kostyakov,
Vladislav G. Volkov

ABSTRACT

OBJECTIVES: Our goal was to create a new model to predict mortality in patients with severe burns using logistic regression.

MATERIALS AND METHODS: We analyzed the scientific literature and conducted a retrospective study of 330 patients over 18 years old with shock-related burn injury who were treated in the Department of Anesthesiology and Resuscitation under the Department of Thermal Injuries of the Saint-Petersburg I. I. Dzhanlidze Research Institute of Emergency Medicine from 2013 to 2019.

RESULTS: In the process of studying the burn cases, 69 factors were identified, reflecting the clinical picture of patients with severe burns and accounting for infusion therapy administration. During construction of the logistic regression, 18 indicators were used that had statistically significant differences ($P < .05$) and in the aggregate made it possible to create a new prediction model. We found the resulting model to be highly efficient, predicting death and recovery with an accuracy of 87% and 93%, respectively.

CONCLUSIONS: The use of a logistic regression method made it possible to create a new formula for predicting mortality in patients with severe burns, taking into account the main factors in the pathogenesis of severe burn injury upon admission and the effectiveness of infusion therapy in the first 3 days of hospitalization. This technique, based on the analysis of 330 patients with severe burns, showed high accuracy, with the ability to be used in everyday practice.

KEY WORDS: *Burn disease, Death, Infusion therapy, Prognosis*

INTRODUCTION

Burn injuries are a threatening condition and a central reason for mortality in patients with skin burns. According to statistics, every year among 400 to 500 thousand patients with severe burns, 6.9% of treatment ends in death. This rate has remained at a high level and so far has not had a downward trend. Therefore, prediction at the early stages of administration of high-tech medical care to patient with burn injuries is important, both in predicting the results of treatment and in standardizing therapy for patients with burns.^{1,2} Today, there are many methods used in the daily practice of combustiologists to predict the results of treatment. The most famous are the Baux index, ABSI, Rayn, McGwin, and the Belgian Outcome of Burn Injury (BOBI).³⁻⁵ Among domestic models in Russia, the Matveenko AV scale is often used as well as the Frank index of lesion severity.^{6,7} These models are based on patient age, area of superficial and deep burns, and the presence of inhalation trauma as predictors of death and do not include the clinical manifestations of the burn injury and the infusion therapy. There are also modified international scales that assess the general condition of the patient that do consider indicators of vital functions (eg, APACHE II, SAPS, and SOFA).^{7,8} However, these do not consider the specifics of the burn injuries and the dynamics of laboratory parameters during treatment and are based only on the determination of isolated markers of trauma severity.⁹ Thus, predicting mortality in severely burned patients continues to be an important and not fully resolved problem in the daily practice of a combustiologist. In addition, the existing models can have different prognosis of treatment results, and none of the models contains an accurate picture of the pathogenesis of burn disease, which raises doubts about the prognostic capabilities of the existing algorithms. The development of a new high-precision method that considers the clinical manifestations of severe

From the Saint-Petersburg I. I. Dzhanlidze Research Institute of Emergency Medicine, St. Petersburg, Russia

ACKNOWLEDGEMENTS: The authors have not received any funding or grants in support of the presented research or for the preparation of this work and have no declarations of potential conflicts of interest.

CORRESPONDING AUTHOR: Oleg Olegovich Zavorotnii, Saint-Petersburg I. I. Dzhanlidze Research Institute of Emergency Medicine, Budapestskaya st. 3 lit. A, 192242 St. Petersburg, Russia

E-mail: o.zavorotnii@hotmail.com

Burn Care and Prevention 2021/2: 53-59

burn injury and the influence of infusion therapy at the early stages is an urgent task in combustiology.

MATERIALS AND METHODS

This study included a retrospective analysis of 330 results of treatment of patients with severe burns who were treated in the Department of Anesthesiology and Resuscitation under the Department of Thermal Injuries of Saint-Petersburg I. I. Dzhanlidze Research Institute of Emergency Medicine from 2013 to 2019. During analyses of the literature and case histories, 69 factors were identified that reflected features of the clinical course of burns, taking into account infusion therapy. There were 4 groups of indicators: (1) incoming data (age, area and depth of the burn, presence of inhalation trauma and alcohol intoxication, carbon monoxide poisoning, postponement of medical care); (2) laboratory indicators (clinical and biochemical parameters, including blood tests, gas composition, and coagulogram results, as well as clinical analysis of urine); (3) results of instrumental studies (blood pressure, pulse, body temperature on the first day of hospitalization); and (4) peculiarities of therapeutic measures and their effectiveness during the first 3 days of hospitalization (parameters of infusion therapy, water consumed, and diuresis).

Statistical analyses

Obtained data were analyzed with the R language statistical program. Results with $P < .05$ were considered statistically significant. Descriptive statistics are presented as mean $\pm$ SD. Logistic regression with stepwise deviation was chosen as a method for constructing a forecasting model and obtaining an algorithm to calculate the probability of death in patients with severe burns. With the use of t tests for independent samples, a comparative analysis of indicators was performed in 2 groups of patients (those who recovered vs those with lethal outcomes). Kolmogorov-Smirnov criteria revealed that most of the

studied parameters showed normal distribution patterns, which is why parametric statistics was chosen. Sample size, parameters with quantitative values, and the presence of a step-by-step exclusion mechanism when constructing a logistic regression determined the admissibility of using this criterion and allowed an additional selection of variables to improve the quality of the model.

The use of a 4-field contingency table, receiver operating characteristic (ROC) analysis, and area under the curve (AUC) indicators allowed us to determine the quality of the resulting model.

RESULTS

Descriptive statistics

Among patients with severe burns, there were 178 patients who survived after treatment (recovered group) and 152 patients with fatal outcomes after treatment (fatal outcome group). Average age in the entire sample was 52.8 ± 19.0 years. The average age in the fatal outcome group (61.3 ± 20.2 y) was higher than the age of patients in the recovered group (47.8 ± 16.3 y). The average surface burn area for the entire sample was $32.5\% \pm 19.4\%$, with $40.3\% \pm 21.1\%$ shown in the fatal outcome group and $28\% \pm 16.8\%$ in the recovered group. The average size of the deep burn area in patients upon admission was $14.9\% \pm 16.2\%$. In the fatal outcome group, the area of deep lesion ($25.4\% \pm 19.9\%$) was higher than that shown in the recovered group ($8.7\% \pm 9.0\%$). Table 1 presents descriptive statistics for the entire patient cohort.

Thermal injury mortality prediction model

Using t tests for independent samples, we selected statistically significant differences shown between the groups of patients who recovered versus those with fatal outcome for the prediction model for burn injury treatment. The results are shown in Table 2.

TABLE 1. Descriptive Statistics for the Entire Cohort of Patients With Severe Burns

Indicator	Overall	Recovered Group	Fatality Group
Age, y	52.8 $\pm$ 19.0	47.8 $\pm$ 16.3	61.3 $\pm$ 20.2
Surface burn area, %	32.5 $\pm$ 19.4	28 $\pm$ 16.8	40.3 $\pm$ 21.1
Deep burn area, %	14.9 $\pm$ 16.2	8.7 $\pm$ 9.0	25.4 $\pm$ 19.9
Postponement of treatment, h	35 $\pm$ 112.7	37.1 $\pm$ 128.3	31.5 $\pm$ 79.6
Body temperature, °C	36.2 $\pm$ 1.2	36.6 $\pm$ 1.0	35.7 $\pm$ 1.3
Systolic blood pressure, mm Hg	137.6 $\pm$ 24.5	138.7 $\pm$ 21.9	135.8 $\pm$ 28.3
Diastolic blood pressure, mm Hg	79.6 $\pm$ 12.1	80.7 $\pm$ 11.1	77.8 $\pm$ 13.4
Heart rate, beats/min	94 $\pm$ 14.9	92.1 $\pm$ 13.2	97.3 $\pm$ 17.1
Respiratory rate, breaths/min	18.1 $\pm$ 5.0	18.1 $\pm$ 5.6	18.2 $\pm$ 3.7
Fibrobronchoscopy, degree of inhalation injury	1.3 $\pm$ 1.2	1.2 $\pm$ 1.2	1.4 $\pm$ 1.3
Concentration of CO ₂ in blood, %	13.7 $\pm$ 11.5	13.9 $\pm$ 11.7	13.4 $\pm$ 11.2
Concentration of ethanol in blood, g/L	0.6 $\pm$ 1.1	0.7 $\pm$ 1.2	0.5 $\pm$ 1.1
Concentration of ethanol in urine, g/L	0.8 $\pm$ 1.4	0.9 $\pm$ 1.4	0.6 $\pm$ 1.3
Blood hemoglobin, g/L	146.2 $\pm$ 22.5	148.8 $\pm$ 20.3	141.7 $\pm$ 25.4

TABLE 1(Cont.). Descriptive Statistics for the Entire Cohort of Patients With Severe Burns

Indicator	Overall	Recovered Group	Fatality Group
Content of large platelets, %	32 ± 15.2	32.3 ± 18.1	31.5 ± 7.9
Average platelet volume, fL	11 ± 4.8	10.7 ± 1.0	11.5 ± 7.8
Neutrophils absolute index, 10 ⁹ /L	12.2 ± 5.7	12 ± 5.0	12.6 ± 6.8
Segmented neutrophils, %	71.7 ± 12.7	70.5 ± 12.5	73.7 ± 12.7
Stab neutrophils, %	10.2 ± 9.6	10.5 ± 10.0	9.7 ± 8.8
Erythrocytes in the blood, 10 ¹² /L	4.7 ± 0.8	4.7 ± 0.7	4.6 ± 0.9
Platelet count in the blood, 10 ⁹ /L	241.8 ± 126.6	218.2 ± 97.9	282.3 ± 157
Leukocytes in the blood, 10 ⁹ /L	14.8 ± 6.3	14.7 ± 5.5	15 ± 7.6
Lymphocytes absolute value, 10 ⁹ /L	1.7 ± 1.8	1.7 ± 1.7	1.7 ± 2.0
Lymphocytes, %	11.5 ± 7.5	11.6 ± 7.4	11.3 ± 7.8
Eosinophils in the blood, 10 ⁹ /L	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.3
Monocytes in the blood, 10 ⁹ /L	1 ± 0.7	1 ± 0.6	1 ± 0.8
Hematocrit, %	42.1 ± 6.2	42.4 ± 5.7	41.6 ± 7.1
Average hemoglobin content in EC, pg	31.5 ± 3.4	31.6 ± 3.2	31.3 ± 3.6
Average concentration of hemoglobin in EC, g/dL	348 ± 21.9	351.8 ± 20.8	341.4 ± 22.3
Platelet distribution index, fL	14.3 ± 4.0	14 ± 2.8	14.8 ± 5.4
EC distribution index by volume, fL	47.8 ± 7.5	46.4 ± 6.9	50.3 ± 7.9
Erythrocyte distribution index relative to average volume, %	14.7 ± 2.1	14.3 ± 1.9	15.4 ± 2.3
Neutrophils in the blood, %	79.7 ± 12.4	78.8 ± 14	81.1 ± 9.1
ESR, mm/h	17.2 ± 17.2	14.9 ± 14.6	21.1 ± 20.3
Total blood protein, g/L	62 ± 12	65.3 ± 9.6	56.5 ± 13.6
C-reactive protein, mg/L	57.6 ± 74.7	35.1 ± 54.2	88.7 ± 88.4
Blood albumin, g/L	32.9 ± 6.9	33.8 ± 6.3	29.4 ± 8.5
Blood urea, mmol/L	6.6 ± 4.8	5.5 ± 3.6	8.5 ± 5.8
Blood creatinine, μmol/L	91.6 ± 57.1	79.5 ± 29.6	112.4 ± 81.9
AST in the blood, U/L	91 ± 193.8	55.1 ± 71.3	152.4 ± 296.1
ALT in blood, U/L	54.5 ± 133.2	39.7 ± 68.1	80 ± 198.6
Total bilirubin, μmol/L	13.7 ± 9.2	12.2 ± 7.9	16.3 ± 10.7
Blood glucose, mmol/L	7.9 ± 3.4	7.4 ± 3.1	8.8 ± 3.7
Sodium in the blood, mmol/L	141.1 ± 6.6	140.2 ± 5.2	142.7 ± 8.3
Potassium in the blood, mmol/L	4.2 ± 0.7	4.1 ± 0.5	4.4 ± 0.9
Prothrombin time, s	14.5 ± 2.2	14.2 ± 1.7	15 ± 2.8
Prothrombin activity according to Quick, s	87.1 ± 18.6	88.7 ± 16.2	84.5 ± 21.9
APTT, s	31.8 ± 15.5	32.8 ± 18.3	30 ± 8.8
INR	1.2 ± 1.6	1.1 ± 0.2	1.4 ± 2.6
Po ₂ , mm Hg	40.1 ± 10.9	40.6 ± 10.9	39.2 ± 11
BE, mmol/L	-6 ± 7.3	-4.4 ± 5.2	-8.8 ± 9.3
Pco ₂ , mm Hg	42.6 ± 10.6	41.5 ± 7.5	44.4 ± 14.3
Fio ₂ , %	31.2 ± 14.9	29.5 ± 15.0	34 ± 14.4
Relative density of urine	1 ± 0	1 ± 0	1 ± 0
pH of urine	5.8 ± 0.8	6 ± 0.8	5.4 ± 0.8
Glucose in urine, mmol/L	7.2 ± 15.3	5.9 ± 13.9	9.5 ± 17.2
Leukocytes in urine (in the field of view)	0.5 ± 1.2	0.2 ± 0.8	0.8 ± 1.5
RBCs in urine (in field of view)	1 ± 1.7	0.7 ± 1.4	1.5 ± 1.9
Protein in urine, g/L	0.4 ± 1.0	0.3 ± 0.6	0.7 ± 1.3
Blood lactate, mmol/L	3.4 ± 2	2.9 ± 1.6	4.2 ± 2.4
Day 1 infusion, L	7.3 ± 4.2	6.6 ± 3.5	8.5 ± 4.9
Diuresis on day 1, L	1.9 ± 1.5	2.2 ± 1.6	1.4 ± 1.3
Day 2 infusion, L	6.2 ± 3.9	5 ± 3.1	8.4 ± 4.2
Diuresis on day 2, L	3.6 ± 2.2	4.1 ± 2.4	2.5 ± 1.5
Day 3 infusion, L	4.3 ± 2.9	3.5 ± 2.2	5.7 ± 3.3
Diuresis on day 3, L	3.3 ± 2.0	3.8 ± 2.0	2.4 ± 1.8
Water intake on day 1, L	1.1 ± 0.9	1 ± 0.9	1.4 ± 0.8
Water intake on day 2, L	1.9 ± 0.4	1.9 ± 0.3	1.8 ± 0.6
Water intake on day 3, L	1.9 ± 0.5	2 ± 0.2	1.8 ± 0.7

Abbreviations: ALT, alanine aminotransferase; APTT, activated partial thromboplastin time; AST, aspartate aminotransferase; BE, base excess; EC, erythrocytes; ESR, erythrocyte sedimentation rate; Fio₂, oxygen concentration in inspired air; INR, international normalized ratio; RBC, red blood cell

TABLE 2. Statistically Significant Differences Between Recovered and Fatal Outcome Groups According to *t* Test

Variable	<i>t</i> Test	<i>P</i> Value	Average for Recovered Group	Average for Fatal Outcome Group
Age, y	-5.82	<.001	47.8 ± 16.3	61.3 ± 20.2
Superficial burn area, %	-5.09	<.001	28 ± 16.8	40.3 ± 21.1
Deep burn area, %	-8.06	<.001	8.7 ± 9.0	25.4 ± 19.9
Body temperature, °C	5.70	<.001	36.6 ± 1.0	35.7 ± 1.3
Heart rate, beats/min	-2.68	<.001	92.1 ± 13.2	97.3 ± 17.1
Hemoglobin in blood, g/L	2.43	.02	148.8 ± 20.3	141.7 ± 25.4
Segmented neutrophils, %	-2.04	.04	70.5 ± 12.5	73.7 ± 12.7
Platelets in blood, 10 ⁹ /L	-3.76	<.001	218.2 ± 97.9	282.3 ± 157.0
Average concentration of hemoglobin in EC, g/dL	3.87	<.001	351.8 ± 20.8	341.4 ± 22.3
EC volume distribution index	-4.09	<.001	46.4 ± 6.9	50.3 ± 7.9
Erythrocyte distribution index relative to the average volume, %	-4.10	<.001	14.3 ± 1.9	15.4 ± 2.3
ESR, mm/h	-2.75	<.001	14.9 ± 14.6	21.1 ± 20.3
Total blood protein, g/L	5.74	<.001	65.3 ± 9.6	56.5 ± 13.6
C-reactive protein, mg/L	-2.30	.02	35.1 ± 54.2	88.7 ± 88.4
Urea, mmol/L	-4.77	<.001	5.5 ± 3.6	8.5 ± 5.8
Creatinine, μmol/L	-3.95	<.001	79.5 ± 29.6	112.4 ± 81.9
Blood AST, U/L	-3.29	<.001	55.1 ± 71.3	152.4 ± 296.1
Blood ALT, U/L	-2.00	.05	39.7 ± 68.1	80 ± 198.6
Total bilirubin in the blood, μmol/L	-3.39	<.001	12.2 ± 7.9	16.3 ± 10.7
Blood glucose, mmol/L	-3.34	<.001	7.4 ± 3.1	8.8 ± 3.7
Blood sodium, mmol/L	-2.70	.01	140.2 ± 5.2	142.7 ± 8.3
Blood potassium, mmol/L	-2.45	.02	4.1 ± 0.5	4.4 ± 0.9
Prothrombin time, s	-2.67	.01	14.2 ± 1.7	15.0 ± 2.8
BE, mmol/L	4.50	<.001	-4.4 ± 5.2	-8.8 ± 9.3
Fio ₂	-2.51	.01	29.5 ± 15	34 ± 14.4
pH of urine	5.48	<.001	6.0 ± 0.8	5.4 ± 0.8
Leukocytes in urine	-3.69	<.001	0.2 ± 0.8	0.8 ± 1.5
Red blood cells in urine	-3.63	<.001	0.7 ± 1.4	1.5 ± 1.9
Protein in urine, g/L	-2.92	<.001	0.3 ± 0.6	0.7 ± 1.3
Blood lactate, mmol/L	-4.93	<.001	2.9 ± 1.6	4.2 ± 2.4
Day 1 infusion, L	-3.40	<.001	6.6 ± 3.5	8.5 ± 4.9
Diuresis on day 1, L	4.64	<.001	2.2 ± 1.6	1.4 ± 1.3
Day 2 infusion, L	-7.12	<.001	5.0 ± 3.1	8.4 ± 4.2
Diuresis on day 2, L	6.86	<.001	4.1 ± 2.4	2.5 ± 1.5
Day 3 infusion, L	-6.19	<.001	3.5 ± 2.2	5.7 ± 3.3
Diuresis on day 3, L	6.08	<.001	3.8 ± 2.0	2.4 ± 1.8
Water intake on day 1, L	-3.14	<.001	1.0 ± 0.9	1.4 ± 0.8
Water intake on day 3, L	2.41	.02	2.0 ± 0.2	1.8 ± 0.7

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BE, base excess; EC, erythrocytes; ESR, erythrocyte sedimentation rate; Fio₂, oxygen concentration in inspired air

As shown in Table 2, there were reliably significant differences between the recovered group and the fatal outcome group in terms of age, percent area of superficial burn on admission, percent area of deep burn on admission, heart rate, concentration of segmented leukocytes, platelets, width of distribution of erythrocytes in volume, width of distribution of erythrocytes relative to the average volume, erythrocyte sedimentation rate, C-reactive protein, urea concentration, creatinine level, aspartate aminotransferase and alanine aminotransferase, total bilirubin, blood glucose, and sodium and potassium levels. These indicators were all shown to be higher in the fatal outcome group.

In addition, in the fatal outcome group, the following indicators were significantly increased: prothrombin time, oxygenation index (F_{iO_2}), concentration of leukocytes and erythrocytes, and protein and lactate levels. The volume of water consumed on day 1 by patients and the volume of infusion therapy received by patients on day 1, 2, and 3 of hospitalization were also significantly higher in the fatal outcome group.

In patients in the recovered group, indicators such as body temperature, hemoglobin concentration, and average concentration of hemoglobin in the erythrocyte were significantly increased, as well as total protein concentration, base excess, urine pH, and water volume consumption on day 3 of hospitalization. Patients in the recovered group showed significantly increased diuresis on the first, second, and the third day of observation in the hospital. All indicators from Table 2 were used to construct the logistic regression. The resulting model is presented in Table 3.

As a result of the conducted logistic regression (Table 3), predictors that were shown to increase the likelihood of death included patient age, percent area of deep burn, level of segmented leukocytes, concentration of urea and lactate in the blood, concentration of leukocytes and protein in urine, volume of infusion therapy on day 3 of hospitalization, and amount of water consumed on day 1 of treatment.

As shown in Table 3, predictors that significantly reduced the likelihood of death included body temperature, total protein concentration, serum creatinine, F_{iO_2} , urine pH, amount of water consumed on day 3 of treatment, and diuresis on the first, second, and third day of hospitalization.

There were some indicators identified at which the coefficients were approximately equal to zero, including percent area of deep burn, body temperature, number of segmented leukocytes, protein concentration in urine, and urine output on day 1 and day 2 of hospitalization. However, the exclusion of these variables led to a decrease in the quality of the resulting model for predicting a lethal outcome. As a result, 18 predictors were included in the final algorithm.

The accuracy indicators of this model, with a cutoff of the probability of death of 50%, are presented in a 4-field contingency table (Table 4). According to the data presented in Table 4, it can be concluded that this model allowed prediction of the probability of recovery and death of patients with severe burns with an accuracy of 93% and 87%, respectively. The discrepancy resulting from the operation of the model and the outcome of treatment was recorded in 20 patients with fatal outcomes and in 13 patients who survived.

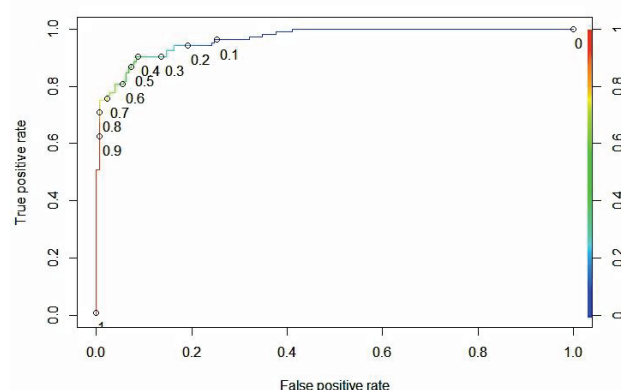
The ROC curve shown in Figure 1 reflects the predictive accuracy of death with different cut-off values; the AUC was 0.97. Our analysis resulted in a model that demonstrated a high accuracy in predicting mortality in patients with severe burns, taking into account the infusion therapy

TABLE 3. Logistic Regression Model Predicting Likelihood of Death From Thermal Injury

Variable	Model Factor	Coefficient Standard Error	Z Value	P Value
(Intercept)	24.00	11.50	2.09	.04
Age	0.04	0.01	3.14	<.001
Deep burn area	0.04	0.02	1.79	.07
Body temperature	-0.47	0.29	-1.65	.10
Segmented neutrophils	0.04	0.02	1.79	.07
Total blood protein	-0.05	0.02	-2.01	.04
Blood urea	0.14	0.07	1.93	.05
Blood creatinine	-0.02	0.01	-2.29	.02
F_{iO_2}	-0.05	0.02	-2.07	.04
pH of urine	-1.14	0.33	-3.41	<.001
Leukocytes in urine	0.57	0.22	2.56	.01
Protein in urine	0.79	0.54	1.48	.14
Blood lactate	0.55	0.14	3.79	<.001
Diuresis on day 1	-0.45	0.25	-1.77	.08
Diuresis on day 2	-0.54	0.19	-2.88	<.001
Day 3 infusion	0.57	0.11	5.00	<.001
Diuresis on day 3	-0.28	0.17	-1.61	.11
Water intake on day 1	0.81	0.32	2.57	.01
Water intake on day 3	-2.29	0.70	-3.27	<.001

TABLE 4. Quadruple Contingency Table for Assessing Model Prediction Accuracy

Exodus	Recovered (predicted)	Fatal Outcome (predicted)	Model Accuracy
Discharged	165	13	93%
Death	20	132	87%

FIGURE 1. Receiver Operating Characteristic Curve Designed by Model

during the first 3 days of hospitalization. We believe this model can be used in everyday practice to both predict and to correct conservative therapy in the early stages of inpatient treatment.

In the process of constructing a logistic regression model, a formula was created to calculate the probability of a lethal outcome with the aim of applying it in medical institutions.

Formula for calculation

The calculation is conducted in 2 stages. In the first stage, the coefficients of the model are multiplied by the values of the predictors for a particular patient. The obtained values are then added to the constant. As a result, we obtained the following natural logarithm of the chance of death (L):

$$L = 24.00 + 0.04 \times [\text{age}] + 0.04 \times [\text{deep burn}] - 0.47 \times [\text{body temperature}] + 0.04 \times [\text{segmented neutrophils}] - 0.05 \times [\text{total protein}] + 0.14 \times [\text{urea}] - 0.02 \times [\text{creatinine}] - 0.05 \times [\text{Fio}_2] - 1.14 \times [\text{urine pH}] + 0.57 \times [\text{urine leukocytes}] + 0.79 \times [\text{protein in urine}] + 0.55 \times [\text{venous blood lactate}] + 0.45 \times [\text{diuresis on day 1}] - 0.54 \times [\text{diuresis on day 2}] + 0.57 \times [\text{infusion on day 3}] - 0.28 \times [\text{urine output on day 3}] + 0.81 \times [\text{water consumed on day 1}] - 2.29 \times [\text{water consumed on day 3}].$$

Next, over the logarithm of the chance, we converted the results to probability (Prob) using the following formula:

$$\text{Prob} = e^L / (e^L + 1)$$

where e is the base of the natural logarithm. For a simplified calculation format, the formula was added to Excel.

When we analyzed the scientific literature with regard to the features of the pathogenesis of burn disease and its manifestations, our recommendation was to assess the likelihood of death in patients with severe burns in 2 stages. In the first stage, the patient's laboratory and instrumental parameters should be assessed upon admission, and infusion therapy then calculated. In the second stage, the

effectiveness of conservative treatment should be assessed and a high-precision prognosis made for each patient, taking into account clinical data.

When the fatality rate is 80% to 90% or more, it is recommended to adjust therapy and surgical tactics for each patient based on laboratory parameters and the results of instrumental studies used in the algorithm of this model.

DISCUSSION

Our resulting forecasting model demonstrated high efficiency and accuracy in determining the outcomes of burn injury. In comparison with its predecessors (Baux, ABSI, Rayn, McGwin, and BOBI), which use only age, surface and deep burn areas, and the presence of inhalation trauma in calculations, this model also considers the specific features of the pathogenesis of shock injury and initial infusion therapy. The developed algorithm showed not only the ability to obtain a highly accurate prediction of the probability of death but also to correct conservative therapy in the early stages of hospitalization. The use of technical capabilities in the form of Microsoft Excel significantly speeds up the process of setting both a preliminary and an accurate forecast for the third day of hospitalization. The use of this model in the daily practice of a combustiologist will make it possible to objectively and to accurately assess the likelihood of death in patients with burn injury at the early stages of medical care, while not requiring a lot of time and high qualifications of a doctor.

CONCLUSIONS

The use of the formula on the first day of hospitalization would allow clinicians to establish a preliminary prognosis for the purpose of sorting patients at treatment and discharge stages.

We found that recalculation on the third day of hospitalization could formulate a highly accurate prognosis and could assess the effectiveness of therapy.

The use of this method in the daily practice of a combustiologist would allow a high-precision prognostic assessment to be quickly obtained on the outcome of a burn injury and could facilitate and increase the effectiveness of predicting death in patients with severe burns, taking into account clinical manifestations and the features of the pathogenesis of burn injury and conservative therapy.

Our resulting model could also allow fluid therapy to be adjusted in the early stages of hospitalization.

REFERENCES

1. Kutuyavin NA, Maratkanov MV, Fatykhova CA, Styazhkina SN. Infectious complications of burn disease. Article in Russian. *Mod Sci.* 2021;4(2):50-53.

2. Evdokimov VI, Kourov AS. Genesis of research on burn injury (analysis of domestic articles in 2005–2017). Article in Russian. *Medico-Biol Socio-Psychol Problems Safety Emergency Situations*. 2018;(4):108-120. doi:10.25016/2541-7487-2018-0-4-108-1203.
3. Hussain A, Dunn K. Burn related mortality in Greater Manchester: 11-year review of Regional Coronal Department Data. *Burns*. 2015;41(2):225-234. doi:10.1016/j.burns.2014.10.008
4. Woods JF, Quinlan CS, Shelley OP. Predicting mortality in severe burns-what is the score?: Evaluation and comparison of 4 mortality prediction scores in an Irish population. *Plast Reconstr Surg Glob Open*. 2016;4(1):e606. doi:10.1097/GOX.00000000000005845.
5. Douglas HE, Ratcliffe A, Sandhu R, Anwar U. Comparison of mortality prediction models in burns ICU patients in Pinderfields Hospital over 3 years. *Burns*. 2015;41(1):49-52. doi:10.1016/j.burns.2014.05.0096.
6. Matveenko AV. Prediction of outcomes of thermal burns. Article in Russian. *Vestn Khir Im I I Grek*. 2009;168(6):101-104.7.
7. Fistal EY, Guryanov VG, Soloshenko VV. Mathematical model of predicting the outcome in victims of methane-coal mixture explosions. Article in Russian. *Russian Sklifosovsky J Emergency Med Care*. 2016;3:43-47.
8. Riley RD, Ensor J, Snell KI, et al. External validation of clinical prediction models using big datasets from e-health records or IPD meta-analysis: opportunities and challenges. *BMJ*. 2016;353:i3140. doi:10.1136/bmj.i31409.
9. Pantet O, Faouzi M, Brusselsaers N, Vernay A, Berger MM. Comparison of mortality prediction models and validation of SAPS II in critically ill burns patients. *Ann Burns Fire Disasters*. 2016;29(2):123-129.