ORIGINAL INVESTIGATION

J Crit Intensive Care 2023;14:33–40
https://doi.org/10.37678/dcybd.2023.3303

Predictors of Mortality for Multiple Trauma Patients with Severe Thoracic Trauma During Intensive Care of The Early Posttraumatic Period

Myroslav STUPNYTSKYI[1], **Oleksii BILETSKYI**[2,3]

[1]Military Medical Clinical Center of the Western Region, ICU of the Cardiovascular Surgery Clinic, Lviv, Ukraine

[2]Kharkiv Clinical Emergency Hospital Named by Prof. O.I. Meshchaninov, Anesthesiology and Intensive Care Department for Patients with Combined Trauma, Kharkiv, Ukraine

[3]Kharkiv National Medical University, Department of Emergency Medicine, Anesthesiology and Intensive Therapy, Kharkiv, Ukraine

Cite this article as: Stupnytskyi M, Biletskyi O. Predctors of Mortality for Multiple Trauma Patients with Severe Thoracic Trauma During Intensive Care of The Early Posttraumatic Period. J Crit Intensive Care 2023;14:33–40

Corresponding Author: Myroslav Stupnytskyi
E mail: stupnytskyima@gmail.com

Received: May 15, 2023
Accepted: May 18, 2023
Available online: Jun 04, 2023

ABSTRACT

Background: Continuous status severity evaluation of the polytraumatized patient during early posttraumatic period is crucial for triage, quality management, assessment of mortality prediction and the scientific study of trauma. The aim of this study was to investigate simple criteria of outcome prediction for multiple trauma patients with severe thoracic trauma during intensive care of the early posttraumatic period.

Methods: This single-center prospective observational cohort study involved 73 adult male polytraumatized patients with blunt mechanism and Abbreviated Injury Scale (AIS) thorax ≥3. The receiver operating characteristic analyses were performed for identification of predictive cut-off values among blood laboratory assays performed on the 1st-2nd, 3rd-4th and 5th-6th days after trauma and the polytrauma scales.

Results: The highest odds ratios for outcome prediction were estimated for the Trauma and Injury Severity Score (TRISS), Revised Trauma Score (RTS) and AIS head. On the 1st-2nd day risk factors for adverse outcome were identified among total protein (TP) concentration, creatinine and oxygen content. On the 3rd-4th day – TP, band neutrophils and white blood cells count. On the 5th-6th day – TP, monocytes and red blood cells count.

Conclusions: Investigated simple criteria can be used for monitoring the clinical course of polytraumatized patients and for recognizing those at high risk of negative outcomes. The same predictive markers can't be used during the whole early posttraumatic period for multiple trauma patients with severe thoracic trauma as specific predictive signs belong to each of the investigated time periods. Predictive powers of estimated markers are different depending on time period.

Key words: Thoracic injuries; Multiple trauma; Blunt injury; Critical care; Hospital mortality; Clinical decision rules.

Introduction

The combination of thoracic trauma with major injuries of the other body regions complicates patient care (1), requires a multidisciplinary approach (2) and involves different specialists (3). Chest trauma is defined as the most important injury in severely injured patients, and it presents in about 50% of those with multiple trauma (4). The presence of an interdisciplinary trauma team with high experience in anaesthesia, critical care and surgical disciplines, especially neurosurgery, trauma surgery, abdominal surgery and thoracic surgery, is mandatory to ensure high-quality management with low morbidity and mortality rates in these patients (5). During the last decade, a reduction of morbidity was observed in multiple traumatized patients admitted to an ICU with severe chest trauma, while mortality rates of them remained unchanged (6). Management strategies of chest injuries has evolved (2) as advances were made in surgical and critical care: surgical repairing of rib fractures (7), early video assisted thoracoscopic surgery (8), non-invasive ventilation (9), multimodal analgesia (10), protective methods of invasive ventilation (5), new forms of patient positioning and extracorporeal oxygenation (11), but are not yet all adopted as the standard of care (12,13). Defining patients that can reach possible benefits from these strategies is also an unsolved problem (2,14). From the other side, rapid communication between all members of trauma team and proper understanding of the disease course with the help of simple and easy for understanding criteria is crucial for enhancing the level of trauma care and could result in better survival in case of multiple trauma with severe thoracic trauma not only in admission and during resuscitative measures, but also during the early posttraumatic period.

Available online at
http://www.jcritintensivecare.org/

Continuous status severity evaluation of the polytraumatized patient during early posttraumatic period is crucial for triage, quality management, assessment of mortality prediction and the scientific study of trauma (13). Another problem of trauma care in middle income countries (as Ukraine is) is limited diagnostic abilities in the lower levels of trauma care centers. So prediction should be based on the simple signs (15).

It's well known that pathophysiology of polytrauma is complex and remains incompletely understood (16,17). It consists of certain stages of systemic reactions with different predominant mechanisms that are responsible for secondary tissue damage, early and late systemic post-injury complications (18,19). In such a setting the same markers can't predict outcome during different time periods.

These all originates point to the importance of detecting the predictive factors affecting the outcome for preparing better treatment strategies by trauma team for polytraumatized patients with severe thoracic injuries at clinical presentation in the initial encounter and during early posttraumatic period.

In this study we aimed to investigate simple criteria of outcome prediction for multiple trauma patients with severe thoracic trauma during intensive care of the early posttraumatic period.

Materials and Methods

Study design

This single-center prospective observational cohort study was conducted on 73 male patients with blunt multiple trauma with severe thoracic trauma that were treated in the anesthesiology and intensive care department for patients with combined trauma of Kharkiv city clinical emergency hospital named by prof. O.I. Meshchaninov.

Patient Selection and Data Collection

Inclusion criteria were ISS≥16, blunt mechanism, two or more injured body regions, AIS thorax ≥3, age ≥18 years. Presence of the concomitant chronic disease in subcompensation or decompensation phase and the penetrating injuries were set as excluding criteria. All patients were treated according to the Advanced Trauma Life Support Program and underwent diagnostic examination according to the existing protocols. Patients` examinations were performed during treatment in the intensive care department on the 1st-2nd (11-34 hours), 3rd-4th (48-75 hours) and 5th-6th (97-122 hours) days after trauma. Simplified formula for blood oxygen content estimation (1.3 × hemoglobin concentration (g/L) × oxygen saturation of hemoglobin (SpO_2) × 0.01) was used. Content of oxygen dissolved in plasma accounts for about 3% of total content, so it can be neglected for simplification of blood oxygen content estimation (20).

Polytrauma severity was evaluated according to the Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), Revised Trauma Score (RTS), Trauma and the Injury Severity Score (TRISS) and Military Field Surgery – Injuries scale (VPH-P) (21–23). All injury severity scores were calculated according to the clinical presentation, imaging results and surgery findings.

Statistical Analysis

Data are reported as Median (95% contingency interval) for ordinal variables, Means ± Standard deviation for continuous variables and numbers (percentage) for categorical variables. Fisher's exact test, Chi-square test for trends and Mann-Whitney U test were used to compare demographic and laboratory data of the patient groups with the help of GraphPad Prism version 5.03. The receiver operating characteristic (ROC) curves were built for variables with statistical significant differences and cut-off values were calculated according to Youden's index (24). In-hospital mortality was defined as the endpoint of the study. All p-values were two-sided, and a value of $p < 0.05$ was considered statistically significant. Table 1 presents the summary statistics of the patient groups.

Ethical Statements

All persons gave their informed consent prior to their inclusion in the study. In case of inability to take informed consent the last one was given by relatives. No patient identifiable data were used in the analysis. This study was approved by Kharkiv National Medical University Ethics Committee (N8/2016, October 5, 2016) in accordance with World Medical Association Declaration of Helsinki.

Results

All 73 patients were admitted into the ICU after surgery in dependence on received injuries. First time examination (the 1st-2nd day) was performed on the next morning after admission.

There were no statistical differences between survivors and non-survivors in terms of age, admission time, percentage of patients with concomitant alcohol exposure, type of chest injuries, involved body regions and etiology of the polytrauma. More severe head injuries were observed in non-survivors (Table 1). The numbers of patients from survival and non-survival groups were 42 and 31, respectively, on the 1st-2nd day, 42 and 23 – on the 3rd-4th and 42 and 21 – on the 5th-6th day after trauma.

Statistical significant differences among laboratory data during observation period are illustrated in Table 2. It can be seen that the dynamics of investigated variables are not similar nor for each laboratory marker through the investigated time period, nor between survivors and non-survivors. The most significant differences between groups of patients with the multiple trauma with severe thoracic trauma on 1st-2nd day after onset of trauma were observed in terms of the total protein, hemoglobin, creatinine concentrations and red blood cells count. For the 3rd-4th day of the early posttraumatic period the most significant differences were found for the total protein and urea concentrations, the stab neutrophils count and percentage of lymphocytes in white blood cells analysis. The oxygen content, concentrations of total protein and hemoglobin were the most different between patients groups on the 5th-6th day after trauma.

Table 1. Characteristics of the survival and non-survival groups of multiple trauma patients with severe thoracic trauma.

Characteristics		Survivors, n (%) 42 (57.5)	Non-survivors, n (%) 31 (42.5)	p value
Age, years, median (95% CI)		41 (38.21 – 44.89)	42 (36.7 – 46.46)	1
ISS, median (95% CI)		24.5 (22.73 – 28.22)	34 (30.38 – 38.53)	0.0006
RTS, median (95% CI)		7.84 (7.05 – 7.68)	6.17 (5.35 – 6.46)	<0.0001
TRISS, median (95% CI)		0.964 (0.871 – 0.961)	0.717 (0.556 – 0.766)	<0.0001
VPH-P, median (95% CI)		7.45 (7.522 – 11.57)	17.9 (13.8 – 20.1)	0.0002
Admission time, hours, median (95% CI)		1 (0.854 – 1.97)	1 (0.435 – 3.297)	0.8434
Controlled mechanical ventilation > 48 h, n (%)		11 (26.2)	20 (64.5)	0.0017
Patients with concomitant alcohol exposure, n (%)		23 (54.7)	15 (48.4)	0.6407
Traumatized body regions				
Craniothoracic, n (%)		6 (14.3)	3 (9.7)	0.0901
Thoracoabdominal, n (%)		3 (7.1)	1 (3.2)	
Thoracoscelethal, n (%)		7 (16.7)	1 (3.2)	
Craniothoracoabdominal, n (%)		5 (11.9)	5 (16.1)	
Craniothoracoscelethal, n (%)		7 (16.7)	7 (22.6)	
Thoracoabdominoscelethal, n (%)		5 (11.9)	2 (6.5)	
Craniothoracoabdominoscelethal, n (%)		9 (21.4)	12 (38.7)	
Injury Severity				
AIS Skin	0, n (%)	18 (42.9)	15 (48.4)	0.7837
	1, n (%)	22 (52.4)	14 (45.2)	
	2, n (%)	2 (4.7)	2 (6.4)	
AIS Head	0, n (%)	18 (42.9)	4 (12.9)	0.0008
	1, n (%)	10 (23.8)	7 (22.6)	
	2, n (%)	1 (2.4)	1 (3.2)	
	3, n (%)	9 (21.4)	7 (22.6)	
	4, n (%)	3 (7.1)	6 (19.4)	
	5, n (%)	1 (2.4)	6 (19.4)	
AIS Facial	0, n (%)	31 (73.8)	24 (77.4)	0.9312
	1, n (%)	10 (23.8)	5 (16.2)	
	2, n (%)	0 (0)	1 (3.2)	
	3, n (%)	1 (2.4)	1 (3.2)	
AIS Thorax	3, n (%)	12 (28.6)	3 (9.7)	0.0772
	4, n (%)	30 (71.4)	28 (90.3)	
AIS Abdomen	0, n (%)	20 (47.6)	11 (35.4)	0.2169
	1, n (%)	11 (26.2)	8 (25.8)	
	2, n (%)	1 (2.4)	2 (6.5)	
	3, n (%)	6 (14.3)	4 (12.9)	
	4, n (%)	4 (9.5)	6 (19.4)	
AIS Extremities	0, n (%)	14 (33.3)	9 (21)	0.6032
	1, n (%)	4 (9.5)	2 (6.5)	
	2, n (%)	9 (21.4)	7 (22.6)	
	3, n (%)	13 (31.1)	12 (38.7)	
	4, n (%)	2 (4.7)	1 (3.2)	
Chest injuries				
Unilateral pneumothorax, n (%)		20 (47.6)	11 (35.4)	0.3446
Unilateral hemothorax, n (%)		18 (42.9)	9 (29)	0.3268
Bilateral hemo- / pneumothorax, n (%)		2 (4.7)	5 (16.2)	0.1269
Hemo- / pneumomediastinum, n (%)		4 (9.5)	2 (6.5)	1
Unilateral lung contusion, n (%)		27 (64.3)	20 (64.5)	1
Bilateral lung contusion, n (%)		1 (2.4)	4 (12.9)	0.1559
Heart contusion, n (%)		28 (66.7)	23 (74.2)	0.6081
Rib fractures <3, n (%)		8 (19)	5 (16.2)	1
Rib fractures ≥ 3, n (%)		25 (59.5)	16 (51.6)	0.6338
Flail chest, n (%)		1 (2.4)	0 (0)	1
Sternum fracture, n (%)		1 (2.4)	1 (3.2)	1
Thoracic spine fracture, n (%)		0 (0)	3 (9.7)	0.0723
Diaphragmatic rupture, n (%)		1 (2.4)	0 (0)	1
Subcutaneous emphysema, n (%)		9 (21.4)	4 (12.9)	0.5373
Bilateral chest injuries, n (%)		5 (11.9)	5 (16.2)	0.7343
Mechanism of injury				
Car driver, n (%)		13 (31.1)	3 (9.7)	0.1216
Bicycle accident, n (%)		3 (7.1)	2 (6.5)	
Car passenger, n (%)		1 (2.4)	4 (12.9)	
Pedestrain, n (%)		9 (21.4)	6 (19.4)	
Falls from height, n (%)		11 (26.2)	13 (41.9)	
Assault, n (%)		3 (7.1)	1 (3.2)	
Crushed by the heavy object, n (%)		1 (2.4)	1 (3.2)	
Injury by manufacture machines, n (%)		1 (2.4)	1 (3.2)	

*__95% CI:__ 95% contingency interval, __AIS:__ Abbreviated injury scale, __ISS:__ Injury Severity Score, __RTS:__ Revised Trauma Score, __TRISS:__ Trauma and the Injury Severity Score, __VPH-P:__ Military Field Surgery – Injuries scale

Table 2. Laboratory data dynamics in the blunt multiple trauma patients with severe thoracic trauma.

	Groups	The 1st-2nd day	The 3rd-4th day	The 5th-6th day
Hemoglobin, g/L (mean ± SD)	S	121.2±22.28	107.9±22.22	112.2±17.81
	NS	98.18±22.43 p<0.0001	89.99±17 p=0.002	92.41±12.86 p<0.0001
Hematocrit, % (mean ± SD)	S	37.69±6.914	31.95±7.076	33.87±5.766
	NS	30.96±7.194 p=0.0002	28.84±4.75 p=0.3471	29.02±4.165 p=0.0014
Red blood cells count, $\times10^{12}$/L (mean ± SD)	S	4.08±0.65	3.71±0.689	3.87±0.567
	NS	3.37±0.707 p<0.0001	3.24±0.595 p=0.0179	3.35±0.433 p=0.001
Oxygen content, mL/L (mean ± SD)	S	150.2±28.72	131.9±29.09	137.8±22.09
	NS	122.9±28.53 p=0.0004	111.9±20.7 p=0.0073	111.8±19.81 p<0.0001
Total protein, g/L (mean ± SD)	S	54.54±4.853	52.59±5.782	57.71±8.511
	NS	47.34±5.544 p<0.0001	46.66±4.449 p=0.0001	47.08±5.139 p<0.0001
Urea, mmol/L (mean ± SD)	S	6.34±1.639	6.85±1.467	8.16±2.128
	NS	7.42±1.353 p=0.0015	9.69±3.437 p=0.0005	11.39±5.51 p=0.0027
Creatinine, µmol/L (mean ± SD)	S	131.2±47.49	140.8±61.01	134.3±49.49
	NS	172.1±41.89 p<0.0001	190±58.35 p=0.0028	192.1±77.49 p=0.0007
White blood cells count, $\times10^{9}$/L (mean ± SD)	S	12.25±4.803	10.46±3.475	11.88±3.056
	NS	12.37±4.869 p=0.9289	13.55±3.486 p=0.0011	15.76±7.422 p=0.0391
Eosinophils, $\times10^{6}$/L (mean ± SD)	S	12.93±41.2	45.42±89.53	60.07±75.63
	NS	22.06±48.79 p=0.2587	73.11±83.85 p=0.0826	63.8±78.99 p=0.8801
Band neutrophils, x10^{6}/L (mean ± SD)	S	1876±1588	1008±767.9	1070±767.6
	NS	1788±1403 p=0.6433	2511±1752 p=0.0002	2791±2535 p=0.0008
Segmented neutrophils, x10^{6}/L (mean ± SD)	S	8117±3225	7222±2396	7599±2129
	NS	8759±3555 p=0.4057	9289±2774 p=0.0034	10071±5675 p=0.0534
Lymphocytes, x10^{6}/L (mean ± SD)	S	1711±1266	1610±999.2	2350±1158
	NS	1220±569.7 p=0.2093	1205±407.8 p=0.2815	2189±1235 p=0.5845
Monocytes, x10^{6}/L (mean ± SD)	S	617±626.1	576.5±446.7	795.4±466.8
	NS	583.8±382.6 p=0.596	465.7±275.5 p=0.706	629±681.2 p=0.0061
Eosinophils, % (mean ± SD)	S	0.09±0.297	0.38±0.66	0.52±0.594
	NS	0.19±0.402 p=0.2341	0.52±0.593 p=0.2177	0.42±0.507 p=0.6227
Band neutrophils, % (mean ± SD)	S	14.12±8.06	9.304±6.43	8.757±4.51
	NS	13.44±6.81 p=0.9777	18.46±11.22 p=0.0013	17.62±13.47 p=0.0085
Segmented neutrophils, % (mean ± SD)	S	67.26±13.57	69.79±11.3	64.57±10.58
	NS	71.52±8.664 p=0.2861	68.57±10.79 p=0.6019	63.29±14.93 p=0.7760
Lymphocytes, % (mean ± SD)	S	13.3±7.08	14.85±7.32	19.41±7.52
	NS	10.18±4.08 p=0.0462	9±2.49 p<0.0001	14.66±6.86 p=0.0132
Monocytes, % (mean ± SD)	S	5.188±4.142	5.628±4.412	6.706±3.244
	NS	4.754±2.472 p=0.9105	3.385±1.598 p=0.0022	3.875±2.317 p=0.0001

*SD: standard deviation, S: group of survived patients, NS: group of patient who did not survive

Laboratory markers and the polytrauma severity scales were selected for ROC-analysis based on the degree of difference between patient groups (p-values) for each time period. Figure 1 represents built ROC-curves with the highest values of Areas under receiver operating characteristic curve (AUROC) for laboratory markers and the polytrauma severity scales. The highest value of AUROC among polytrauma severity scales was obtained for the TRISS model.

The results of ROC-analyses and discriminative statistics for investigated cut-off values are summarized in Table 3. For the determination of cut-off values the Youden's index was used.

According to the contingency table statistics, among polytrauma predictive models the most significant influence on probability of mortality for multiple trauma patients with severe thoracic trauma has TRISS model with cut-off <0.834. The most relevant predictive laboratory marker of negative outcome through investigated period of polytrauma was total protein concentration. But its cut-off values were different for each time period: <49.36 g/L for the 1st-2nd day, <53.83 g/L for the 3rd-4th day and <53.49 g/L for the 5th-6th day of the early posttraumatic period. Also for the 3rd-4th day after trauma the highest value of AUROC was estimated for percentage of lymphocytes in leukocyte formula with cut-off <10.03%, indicating possibility of more accurate than according to total protein concentration negative outcome prediction for multiple trauma patients with severe thoracic trauma during this time period.

Discussion

Polytrauma patients are always challenging, especially when they have suffered severe chest injuries (5). The majority of thoracic trauma cases can be managed conservatively, but in the presence of severe injuries to the chest it may require extended surgical

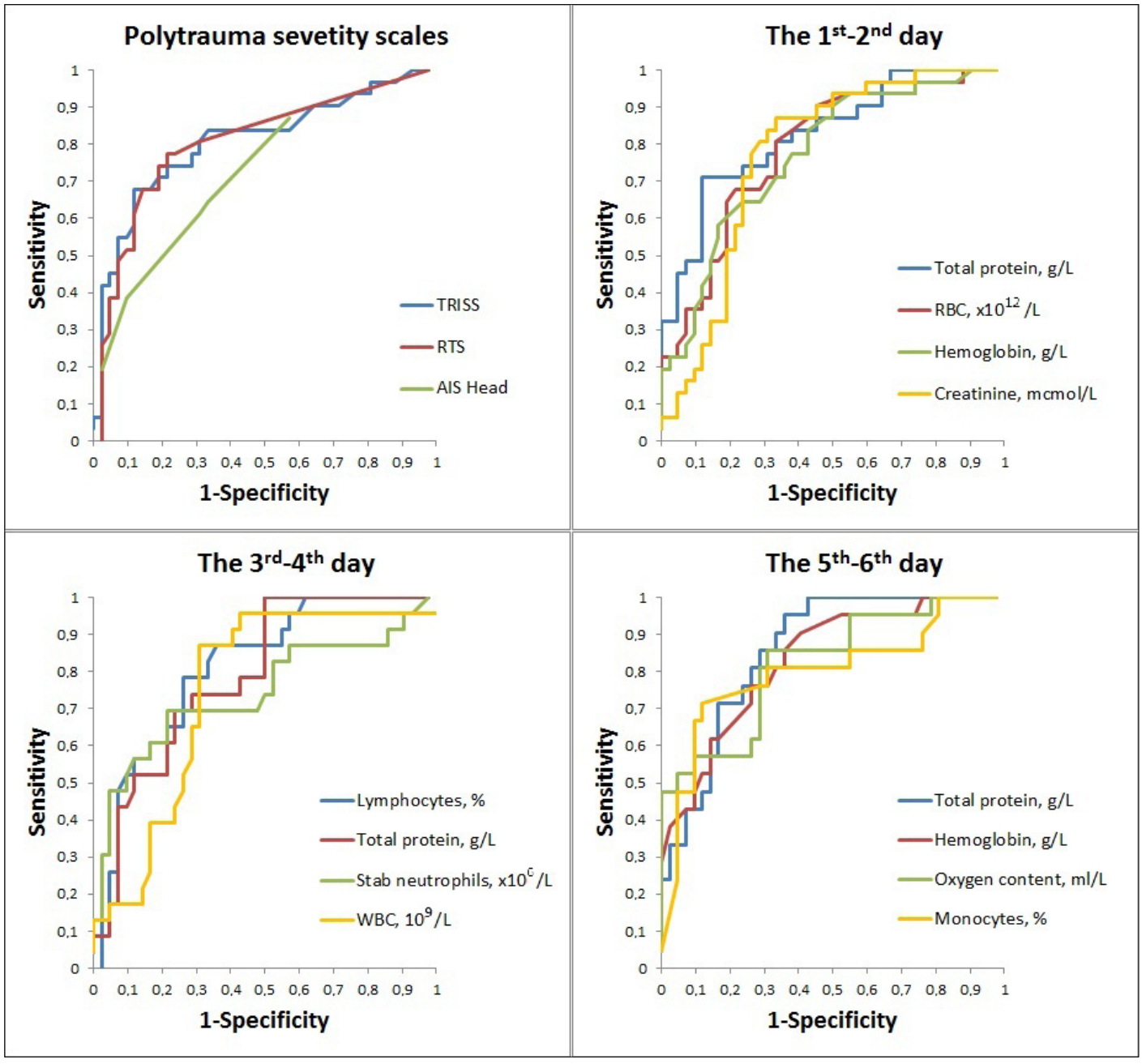

Figure 1. The Receiver operating characteristic curves of the investigated polytrauma severity scales and laboratory data during early posttraumatic period in case of multiple trauma with severe thoracic trauma. **AIS:** Abbreviated injury scale, **RTS:** Revised Trauma Score, **TRISS:** Trauma and the Injury Severity Score, **RBC:** Red blood cells, **WBC:** White blood cells.

and intensive care measures as a definitive management because clinical features of this type of polytrauma differ and vary from a simple injury to life-threatening condition (25). The severity of multiple trauma with severe thoracic trauma should be evaluated immediately by considering vital signs, injury mechanism and clinical presentation. However, the clinical appearance can often be misleading at the first time and complications may take 48-72 hours to emerge (2). Organ dysfunction and multiple organ failure syndromes, as other systemic complications, are more frequent especially in case of severe thoracic traumas (4). Risk stratification on admission is important, but also needs to be assessed after surgery and resuscitative measures as intensive care during early posttraumatic period represents another turning point and needs simple, easy to performed and accurate predictive tools for the identification of those patients at high risk for negative outcomes for appropriate early intervention and supportive care (26,27). The majority of research dedicated to the outcome prediction for thoracic trauma victims has been focused primarily on polytrauma in general or isolated thoracic injuries only and covers time periods on admission or first 24 hours after onset of trauma (4,5,28). According to available data for us, this is the first study for determining mortality risk criteria for blunt multiple trauma patients with severe thoracic trauma during early posttraumatic period. This study propose simple predictive criteria with good discrimination statistics for categorizing into greater-risk of in-hospital mortality for such polytrauma patients during three

Table 3. Cut-off values and areas under receiver operating characteristic curves.

	AUROC	Cut-Off	LR	Odds ratio (95% CI)	p value
RTS	0.8061 ± 0.05428; p<0.0001	<7.004	3.613	12.57 (4.105 – 38.5)	<0.0001
TRISS	0.8076 ± 0.05439; p<0.0001	<0.8339	5.69	15.54 (4.681 – 51.59)	<0.0001
VPH-PMT	0.7569 ± 0.05717; p=0.00019	>15.15	2.71	6.889 (2.443 – 19.43)	0.0003
AIS Head	0.7266 ± 0.05998; p=0.001	> 0	1.524	5.063 (1.502 – 17.07)	0.0091
		> 1	1.935	3.636 (1.37 – 9.654)	0.0101
		> 2	1.98	3.532 (1.332 – 9.365)	0.0165
		> 3	4.065	6 (1.704 – 21.13)	0.0041
		> 4	8.129	9.84 (1.118 – 86.63)	0.0372
The 1st-2nd day after trauma					
Hemoglobin, g/L	0.7761 ± 0.05448; p<0.0001	<104	3.484	6.923 (2.349-20.4)	0.0004
Hematocrit, %	0.7565 ± 0.05811; p=0.00019	<33.53	3.312	8.963 (3.074-26.13)	<0.0001
RBC, $\times 10^{12}$/L	0.788 ± 0.05338; p<0.0001	<3.855	2.419	8.333 (2.779-24.99)	0.0001
Oxygen content, ml /L	0.7431 ± 0.05785; p=0.00042	<147.2	1.897	10.27 (2.699-39.06)	0.0001
Total protein, g/L	0.828 ± 0.04829: p<0.0001	<49.36	5.961	18.09 (5.371-60.92)	<0.0001
Creatinine, µmol/L	0.773 ± 0.05553; p<0.0001	>143.1	2.613	13.5 (3.943-46.23)	<0.0001
Urea, mmol/L	0.7189 ± 0.05994; p=0.0015	>6.115	1.897	10.27 (2.699-39.06)	0.0001
The 3rd-4th day after trauma					
Total protein, g/L	0.7883 ± 0.05588; p=0.00013	<53.83	2	47 (2.678-824.7)	<0.0001
Lymphocytes, %	0.8111 ± 0.05375; p<0.0001	<10.03	2.988	10.15 (3.036-33.9)	<0.0001
Band neutrophils, %	0.7433 ± 0.0708; p=0.00127	>13.5	3.246	8.381 (2.642-26.59)	0.0002
WBC, $\times 10^{9}$/L	0.7469 ± 0.06353; p=0.00107	>11.68	2.809	14.87 (3.745-59.05)	<0.0001
Band neutrophils, $\times 10^{6}$/L	0.7785 ± 0.06357; p=0.00022	>227.6	21.91	44.73 (5.229-382.6)	<0.0001
Segmented neutrophils, $\times 10^{6}$/L	0.7215 ± 0.06509; p=0.00334	>722.6	1.917	11.55 (2.398-55.63)	0.0004
Monocytes, %	0.7314 ± 0.06682; p=0.00218	<3.703	2.988	10.15 (3.036-33.9)	<0.0001
The 5th-6th day after trauma					
Total protein, g/L	0.8571 ± 0.04536; p<0.0001	<53.49	2.667	36 (4.383-295.7)	<0.0001
Band neutrophils, %	0.7052 ± 0.08301; p=0.00834	>11.72	3.5	8.5 (2.585-27.95)	0.0005
Monocytes, %	0.7976 ± 0.06567; p=0.00013	<3.921	6	18.5 (4.892-69.96)	<0.0001
Band neutrophils, $\times 10^{6}$/L	0.7619 ± 0.07660; p=0.00076	>123.5	4	13.6 (3.835-48.23)	<0.0001
Hemoglobin, g/L	0.8322 ± 0.05285; p<0.0001	<101.5	2.909	9.018 (2.669-30.47)	0.0003
Hematocrit, %	0.7483 ± 0.06592; p=0.00142	<29.44	3.714	8.125 (2.452-26.92)	0.0005
RBC, $\times 10^{12}$/L	0.7574 ± 0.06532; p=0.00094	<3.283	10	18.18 (3.461-95.51)	0.0001
Oxygen content, ml/L	0.822 ± 0.05689; p<0.0001	<126.8	2.769	13.38 (3.345-53.56)	<0.0001
Creatinine, µmol/L	0.763 ± 0.06455; p=0.0007	>148.9	2.667	8 (2.392-26.75)	0.0005

95% CI: 95% contingency interval, **LR:** Likelihood ratio, **AUROC:** Area under the receiver operating characteristic curve, **AIS:** Abbreviated injury scale, **RTS:** Revised Trauma Score, **TRISS:** Trauma and the Injury Severity Score, **VPH-P:** Military Field Surgery – Injuries scale, **RBC:** Red blood cells, **WBC:** White blood cells.

time intervals, postulating the fact that the effects on mortality of different risk factors may differ in dependence on the time after trauma insult.

Automobile accidents are the most common cases of blunt injuries, as can be seen in the present study (Table 1) and in studies from other authors (2,25). Beshay et al. (2020) in retrospective mono-center study that involved victims with both types of thoracic trauma – isolated and associated with other body regions, found that the most frequent mechanism of injury are road traffic accidents. Car crashes were the most frequent cause among them, followed by motorcycle crashes and injured pedestrians. In our study the most frequent mechanisms of injury were falls from height followed by car crashes and pedestrians. The possible reason can be that patients only with multiple trauma with severe thoracic trauma were involved in this study (5). The results of ROC-analysis supports that head injury is the most important risk factor for multiple trauma patients with severe thoracic trauma (Table 3). This finding is in accordance with results from other studies in this area linking negative outcomes of polytrauma victims with head injuries (2). Grubmuller et al. (2018) showed that head injuries (AIS>3) were primary causes of death among patients with multiply injuries with severe and mild thoracic injuries (1). Among polytrauma severity scales the highest level of predictive power belongs to TRISS. It is not surprising, because this probability model includes both RTS and ISS scales in its equation that enhances accuracy of mortality prediction. Another interesting finding is the hemoglobin concentration cut-off value < 104 g/L according to Youden's index on the 1st-2nd day after trauma. Such value is higher than set in polytrauma transfusion guidelines (29), but multiple trauma patients with only severe thoracic injuries were included in this study, suggesting that they may benefit from liberal transfusion strategy. Further randomized controlled studies are needed for confirming this value of hemoglobin concentration

as possible target concentration in context of standardized management approach for this population of polytrauma patients. In contrast to the 1st-2nd day high discrimination statistics values were observed for simple markers of immune reaction on the 3rd-4th day after trauma. These results demonstrate activation of the host defense with the maximum on the 3rd-4th day after trauma in accordance with previous articles, dedicated to polytrauma pathophysiology staging (16,17), that's why high predictive significance belongs to WBC count and the leukocyte formula at this time period. It`s well known that in case of severe injuries, later post-injury phase is characterized by the high degree of mortality due to inflammation-related complications, which affect the immune homeostasis and presents in sepsis, septic shock, or multiple organ dysfunction syndrome (18). The results of our study suggests that the dynamics of total protein concentration can reflect the course of disease progression during early posttraumatic period of blunt multiple trauma patients with severe thoracic trauma because good prediction ability of this simple laboratory marker was observed for each estimated time period (Figure 1). These results reflect those of Tabakoglu and Inal (2021) who also found that albumin concentration (main component of plasma proteins) was significantly related to patients' mortality according to multivariate logistic regression analysis in a mixed cohort of ICU admitted patients (15). Contrary to expectations, the cut-off value of the oxygen content of the blood acquires high predictive importance only on the 5th-6th day after trauma. Such result reflects that prolongation (up to the 5th-6th day after trauma) of combined hypoxia (results from both anemia and decrease in hemoglobin saturation) during early posttraumatic period of blunt multiple trauma patients with severe thoracic trauma is more harmful than the degree of this hypoxia.

With the help of these additional criteria trauma team members can provide more objective guidance for decisions to predict survival for multiple trauma patients with severe thoracic trauma according to simple clinical and laboratory data obtained during the early posttraumatic period. As mortality of such polytrauma patients still remains high, about 17% (5,12,13,25), early applied risk-adjusted proper intensive treatment and prevention of specific complications is essential (4). The odds ratios for predictive criteria, estimated for laboratory results produced magnitudes more than 10, indicating strong association between presence of each criterion and lethal outcome in case of multiple trauma with severe thoracic trauma, but absence of the AUROC values more than 0.9 don't give opportunity to suggest either test as a single discriminative marker for triage of the such type of polytrauma patients (24). These investigated predictive markers can help to identify proper timing and extent for second look surgery, when preoperative conditions and risk/benefits aspects must be taken into account for deciding individual indications for additional interventions during early posttraumatic period (13,27,28). Developed risk criteria can help to evaluate new treatment effectiveness like early video assisted thoracoscopic surgery, surgical rib fixation, pain management strategies, non-invasive ventilation and extracorporeal membrane oxygenation whose benefits are controversial yet (1,11,14). It is possible that some therapeutic measures may be effective for the mortality reduction only in certain risk assessment based patient subsets (30). For example, debate still exists on timing of tracheostomy in patients with severe thoracic injuries (31). The use of these simple signs can give the objective picture of the disease severity of blunt multiple trauma patients with severe thoracic trauma in ICU and permits comparison of patients from different trauma centers of various levels of trauma care. This can be helpful in making quick accurate decisions about interhospital transfer too. The comparison of the estimated to observed mortality rates, can serve as evaluation criteria and monitoring of the ICU work quality.

Limitations

Like the other prospective studies this study is not an exception about presence of some limitations, meaning that these findings should be extrapolated to other patients with polytrauma carefully. This is a single-center study, so validation of these prognostic signs in other trauma centers and regions should be performed. Another limitation is that patient groups are similar with respect to age, so it is impossible to analyze the contribution of this factor into the negative outcome. According to previous studies, age is a relevant factor but its contribution to mortality risk in some other studies dedicated to trauma patients with chest injury is not statistically significant (6,25). Also, current study is based on a small sample of participants. Nevertheless, the results of discrimination statistics show that proposed criteria can accurately define patients with high risk of negative outcome. Despite these limitations, our results seem to be significant, are in accordance with other clinical and experimental studies and we hope that our scoring method can improve management of blunt multiple trauma patients with severe thoracic trauma during the early posttraumatic period.

Conclusions

Proposed predictive markers were developed to help estimate individual risk of mortality in blunt multiple trauma patients with severe thoracic trauma through the first 5-6 days of post-traumatic period based upon routine diagnostic tests performed daily in the ICU. Investigated simple criteria can be used for monitoring the clinical course of polytraumatized patients and for recognizing those at high risk of negative outcomes to improve quality of patient care during early intensive focused care. The prognostic values of clinical and laboratory markers are different depending on the time period of the early post-traumatic intensive care. It seems to be not correct to use the same predictive markers during the whole early posttraumatic period for multiple trauma patients with severe thoracic trauma as each of the investigated time periods is characterized by its own specific predictive signs. Predictive powers of estimated markers are different depending on time period. No specific and highly accurate signs were found to be recommended as a single predictive marker of negative outcome.

AUTHOR CONTRIBUTIONS:

Concept: MS, OB; **Design:** MS, OB; **Supervision:** MS, OB; **Resources:** MS, OB; **Materials:** MS; **Data Collection and/or Processing:** MS; **Analysis and/or Interpretation:** MS; **Literature Search:** MS, OB; **Writing Manuscript:** MS; **Critical Review:** OB.

Ethics Committee Approval: This study was approved by Kharkiv National Medical University Ethics Committee, N8/2016, October 5, 2016.

Informed Consent: Patients who met inclusion criteria and agreed to participate or legally authorized kins were asked to provide informed consent.

Peer-review: Externally peer-reviewed.

Conflict of Interest: Authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Presented: 34th Annual Congress of the European Society of Intensive Care Medicine, LIVES Digital 2021, e-poster presentation, October 3-6, 2021.

References

1. Grubmüller M, Kerschbaum M, Diepold E, et al. Severe thoracic trauma - still an independent predictor for death in multiple injured patients? Scand J Trauma Resusc Emerg Med. 2018;26(1):6. [CrossRef]
2. Dogrul BN, Kiliccalan I, Asci ES, et al. Blunt trauma related chest wall and pulmonary injuries: An overview. Chin J Traumatol. 2020;23(3):125–38. [CrossRef]
3. Bouzat P, Raux M, David JS, et al. Formalized expert recommendations chest trauma: first 48 hours management. Anaesth Crit Care Pain Med. 2017;36(2):135–45. [CrossRef]
4. Sibuea D, Pohan DP, Marshal. Thoracic trauma severity score (TTSS) as an outcome predictor of blunt thoracal injury patients in Adam Malik Medan hospital. Int J Res Sci Manag. 2020;7(6):17–24. [CrossRef]
5. Beshay M, Mertzlufft F, Kottkamp HW, et al. Analysis of risk factors in thoracic trauma patients with a comparison of a modern trauma centre: a mono-centre study. World J Emerg Surg. 2020;15(45):1–10. [CrossRef]
6. Horst K, Andruszkow H, Weber CD, et al. Thoracic trauma now and then: A 10 year experience from 16, 773 severely injured patients. PLoS ONE. 2017;12(10):1–14. [CrossRef]
7. Majercik S, Pieracci FM. Chest wall trauma. Thorac Surg Clin NA. 2017;27(2):113–21. [CrossRef]
8. Dennis BM, Bellister SA, Guillamondegui OD. Thoracic trauma. Surg Clin N Am. 2017;97:1047–64. [CrossRef]
9. Schreiber A, Yildirim F, Ferrari G, et al. Non-Invasive mechanical ventilation in critically ill trauma patients: a systematic review. Turk J Anaesthesiol Reanim. 2018;46:88–95. [CrossRef]
10. Gupta A, Pangtey D, Gupta N. Multiple Erector Spinae Plane injections as a component of multimodal perioperative analgesia in polytrauma patient undergoing spine surgery. Turk J Anaesthesiol Reanim. 2021;4(1):2020–1. [CrossRef]
11. Saillant NN, Sein V. Management of severe chest wall trauma. J Emerg Crit Care Med. 2018;2:41. [CrossRef]
12. Marro A, Chan V, Haas B, et al. Blunt chest trauma: classification and management. Emerg Radiol. 2019;26(5):557–66. [CrossRef]
13. Simon JB, Wickham AJ. Blunt chest wall trauma: an overview. Br J Hosp Med. 2019;80(12):711–5. [CrossRef]
14. Ali-osman F, Mangram A, Sucher J, et al. Geriatric (G60) trauma patients with severe rib fractures: Is muscle sparing minimally invasive thoracotomy rib fixation safe and does it improve post-operative pulmonary function? Am J Surg. 2018;216(1):46–51. [CrossRef]
15. Tabakoglu N, Inal V. Evaluation of Basic Parameters for Prediction of ICU Mortality. J Crit Intensive Care. 2021;12:47–52. [CrossRef]
16. Yang B, Bundkirchen K, Krettek C, et al. Traumatic injury pattern is of equal relevance as injury severity for experimental (poly) trauma modeling. Sci Rep. 2019;9(1):1–12. [CrossRef]
17. Stupnytskyi M, Zhukov V, Gorbach T, et al. Analysis of the early posttraumatic period pathophysiology in case of the severe combined thoracic trauma using multivariate logistic regression. CEUR-WSorg Online. 2019;2488:330–9. Available at: https://ceur-ws.org/Vol-2488/paper29.pdf
18. Relja B, Mörs K, Marzi I. Danger signals in trauma. Eur J Trauma Emerg Surg. 2018;44(3):301–16. [CrossRef]
19. Pidruchna SR, Stepanova HM, Pereviznyk BO, et al. Endogenous intoxication in animals of different age groups in case of polytrauma. Int J Med Med Res. 2016;2(2):63–6. [CrossRef]
20. Lilleberg J, Nieminen MS, Akkila J, et al. Effects of a new calcium sensitizer, levosimendan, on haemodynamics, coronary blood flow and myocardial substrate utilization early after coronary artery bypass grafting. Eur Heart J. 1998;19(4):660–8. [CrossRef]
21. Greenspan L, McLellan BA, Greig H. Abbreviated injury scale and injury severity score: a scoring chart. J Trauma. 1985;25(1):60–4. [CrossRef]
22. Champion HR, Copes WS, Sacco WJ, et al. The Major Trauma Outcome Study: establishing national norms for trauma care. Trauma. 1990;30(11):1356–65. [CrossRef]
23. Roshchin GG, Gurev SO, Mazurenko OV, et al. Standardized systems for assessing the injury severity and status of victims. (Teaching manual). Kyiv; 2014. 82 p.
24. Bewick V, Cheek L, Ball J. Statistics review 13: receiver operating characteristic curves. Crit Care Lond Engl. 2004;8(6):508–12. [CrossRef]
25. Hajjar WM, Al-nassar SA. Chest Trauma Experience: Incidence, associated factors, and outcomes among patients in Saudi Arabia. Pak J Med Sci. 2021;37(2):373–8. [CrossRef]
26. Harde M, Aditya G, Dave S. Prediction of outcomes in chest trauma patients using chest trauma scoring system: A prospective observational study. Indian J Anaesth. 2019;63:194–9. [CrossRef]
27. Tisherman SA, Stein DM. ICU management of trauma patients. Crit Care Med. 2018;46(12):1991–7. [CrossRef]
28. Grigorian A, Schubl S, Gabriel V, et al. Analysis of trauma patients with unplanned returns to the operating room. Turk J Surg. 2019;35(1):54–61. [CrossRef]
29. Spahn DR, Bouillon B, Cerny V, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. Crit Care. 2019;23(98):1–74. [CrossRef]
30. Izonin I, Tkachenko R, Ryvak L, et al. Addressing medical diagnostics issues: Essential aspects of the PNN-based approach. CEUR-WSorg Online. 2020;2753:209–18. Available at: https://ceur-ws.org/Vol-2753/paper14.pdf
31. Gillis A, Pfaff A, Ata A, et al. Are there variations in timing to tracheostomy in a tertiary academic medical center? Am J Surg. 2020;219(4):566–70. [CrossRef]