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CLINICAL AND BIOMETRIC ASSESSMENT OF THE SEVERITY OF THE PHYSIOLOGICAL STATUS AND INJURIES IN PATIENTS WITH CONCOFITANT MIDFACE TRAUMA

Scientific specialty: 3.1.2. Maxillofacial surgery

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LIST OF ABBREVIATIONS USED

TBI –traumatic brain injury;

MFR –maxillofacial region;

MZF –middle zone of the face;

ALV –artificial lung ventilation;

–ICU Intensive Care Unit;

MFS –military field surgery;

MST –tactic of multi-stage surgical treatment;

TD –traumatic disease;

HR– heart rate;

INR– International Normalized Ratio;

pH –hydrogen index;

FiO2– fraction of oxygen on inspiration;

PO2 –partial pressure of oxygen in arterial blood;

Na+– sodium ions;

K+ –potassium ions;

GCS – Glasgow Coma Scale;

ISS – Injury Severity Score;

AIS –Abbreviated Injury Scale;

RTS –Revised Trauma Score;

APACHE –Acute Physiology and Chronic Health Evaluation;

ICISS-9– International Classification of Diseases (ICD-9) based Injury Severity Score;

SAPS –Simplified Acute Physiology Score;

SOFA –Sequential Organ Failure Assessment;

TRISS –Trauma and Injury Severity Score;

RISC –Revised Injury Severity Classification;

TMPM is a –Trauma Mortality Prediction Model.

INTRODUCTION

Relevance of the study

The problem of severe concomitant trauma in medicine remains as relevant as ever, despite the active development and introduction of modern technologies in the diagnosis and treatment of patients with traumatic injuries in recent decades [7, 8, 15, 17].

This is due, firstly, to the wide prevalence of various types of injuries in modern society, which is associated with growing urbanisation, accompanied by the wide availability of means of transportation and personal protection [5, 7, 23, 55]. Secondly, to a variety of clinical manifestations of concomitant injuries, the high probability of developing complications in the patients, and the high risk of an unfavourable outcome compared with an isolated injury [45, 48, 49]. Thirdly, traumatism has economic and social consequences due to the fact that the majority of patients are represented by men of working age (20-50 years) [133, 152, 160, 163, 169, 186, 220], and also with high financial costs of treatment and rehabilitation of patients [87, 140].

Among the causes of death of the population in peacetime, concomitant trauma ranks third after oncological diseases and diseases of the cardiovascular system [21, 27, 86, 92, 135, 214] and it is the main cause of mortality of young and able-bodied people [23, 63, 154].

Concomitant craniofacial trauma is among the most severe and life-threatening injuries and is characterised by a violation of the central mechanisms of regulation of various organs and systems of the body [28].

The facial skeleton is usually divided into three anatomical regions: upper, middle and lower. The upper border of the middle zone of the face (MZF) is marked by a line drawn from the zygomatic suture on one side through the upper ocular edges, the left maxillary sutures, and nasolabial sutures to the zygomatic suture on the other side. The lower border of the MZF is located at the level of the occlusal plane of the

teeth of the upper jaw or the alveolar edge, in the case of their absence [40, 91, 101]. The posterior sections of the MFZ are formed by the pterygoid processes of the sphenoid bone [40]. MFZ is composed of the following bones and bone structures: maxillae, zygomatic bones, palatine bones, nasal bones, lacrimal bones, inferior nasal concha, vomer [40, 54, 72], zygomatic processes of the temporal bones, ethmoid bone, and wing processes of the sphenoid bone [40, 72].

MFZ has a complex anatomical structure [29, 73, 82, 101, 159, 190]. The presence of visual analysers, ENT organs, and anatomical proximity to the brain, as well as frequent combination with traumatic brain injury (TBI) [16, 54, 78, 82, 108, 223], frequently cause functional and aesthetic complications in the midface trauma [14, 53, 54]. According to a group of researchers, TBI is combined with midface injuries in 6-30% of cases [44, 95, 100].

The modern concept of treatment of patients with concomitant trauma can be characterised as pathogenetically justified. According to this concept, the extent of medical care required is determined according to the nature of the pathogenetic processes occurring in the injured person after injury and reflecting the severity of his or her physiological status [129].

Thus, assessment of trauma severity is a high priority for modern therapeutic and diagnostic management tactic. This is the basis for deciding on the extent, nature, and order of medical care [31].

The degree of exploration of the research topic

The methods for assessing the severity of injuries have been actively developing since the 70s of the last century. To date, more than 50 scales and methods have been developed to solve this problem. Most of these methods have not survived the test of time. In the last decade, the attention of researchers has been directed to the development of specific methods for assessing the severity of injuries for a specific type of injury or damage to certain organs and anatomical areas.

The main objective of the researchers who studied the problem of midface injury was to develop methods of diagnosis and treatment in order to eliminate local aesthetic and functional impairment after injury and to improve the treatment outcomes of patients with isolated midface trauma.

The authors studying the problems of concomitant midface trauma investigated the timing of reconstructive operations of damaged structures of the maxillofacial region (MFR), the rationale for the tactic of MST taking into account the anatomical structure of the craniofacial skeleton and the effectiveness of the MST tactic in patients with a severe concomitant trauma of the MFR as part of polytrauma [10, 25, 28, 51]. The results of MST tactic in patients with extremely severe concomitant midface trauma as a separate group have not been studied. Indications for individual surgical interventions within the framework of the MST tactic were also not established.

A review of the available literature showed that there have been no scientific studies on the problem of assessing the severity of the physiological status in patients of concomitant midface trauma. There is also a lack of scientific work on the study of signs of dysfunction of vital organs and body systems in the dynamics of the course of traumatic disease, which is extremely important for understanding its pathogenesis and building tactic for multi-stage surgical treatment of patients with this type of injury.

Given the high mortality rate, the risk of infectious and noninfectious, including life-threatening complications, and the increasing number of patients with concomitant midface injuries, this problem requires further study to justify the choice of surgical treatment tactic on an objective basis, taking into account the severity of the physiological status of the patients.

The purpose of the study

To conduct a study of clinical and laboratory signs for an objective assessment of the severity of the physiological status of the patients with concomitant midface trauma, and, based on the results obtained, develop an algorithm for treating patients within the framework of multi-stage surgical treatment tactic.

Objectives of the study

1. To search for syndrome complexes and signs characterising the severity of the physiological status of patients with concomitant midface trauma in the dynamics of the course of traumatic disease.
2. To develop a methodology for predicting the immediate outcomes of concomitant midface trauma.
3. To evaluate the effectiveness of tactic of multi-stage surgical treatment in patients with severe and extremely severe concomitant midface trauma.

Scientific novelty

In the present study, the clinical and laboratory parameters characterising the severity of the physiological status in patients of concomitant midface trauma in the dynamics of the course of traumatic disease were studied for the first time. It has been proved that the nature of morphological relations of the main cells of the immune system and the severity of general intoxication and infectious complications determine the course of the traumatic disease in dynamics. A mathematical model for predicting the probability of developing visceral infectious complications and a model for assessing the severity of combined midface trauma based on objective determinants of severity were developed.

The third post-injury day was found to be the most optimal for predicting the immediate outcome of a concomitant midface trauma. A methodology for predicting the immediate outcome of a concomitant midface trauma has been developed and presented for the first time.

A surgical care algorithm has been established for patients of concomitant midface trauma. The results of multistage surgical treatment tactic on multiple patients with extremely severe concomitant midface trauma were studied for the first time. This has been shown to reduce the likelihood of death and infectious and non-infectious

complications by taking into account the severity of the overall physiological status of the injured person.

Theoretical and practical significance of the work

The main stages of pathogenesis of traumatic disease in patients with concomitant midface trauma have been investigated. Some clinical and laboratory indicators that accurately reflect the severity of functional disruptions of the patients' critical organs and systems in the dynamics of the course of the traumatic disease have been studied.

The significance of the signs characterising morphological and cooperative relations of the main cells of the immune system and indicators of the severity of general intoxication of the organism for evaluation of the severity of the general state of patients in dynamics has been evaluated. The correlations and the level of dependency of these attributes have been revealed.

A comparative biometric analysis algorithm using two-time directions (time course of traumatic disease and time to outcome) and factor analysis based on the principle of shifting all realisations to the same time point with similar clinical significance for the patients studied, followed by a comparative analysis of the identified factors in the dynamics of the course of traumatic disease has been developed.

A rational algorithm for the treatment of patients with extremely severe concomitant midface trauma using the tactic of multistage surgical treatment and taking into account the severity of the physiological status, the prognosis of immediate outcomes and the prognosis of the development of visceral infectious complications which helped to reduce mortality by 17.9% and the incidence of infectious complications by 9.2%, has been established.

The object of research: the man.

Subject of the study: clinical and laboratory physiological signs reflecting the functional state of vital organs and body systems of the patients, spiral computer

tomograms and head X-rays, and case histories of patients with concomitant midface trauma.

Methodology and methods of research

The goal of the work was to investigate clinical and laboratory signs to objectively assess the severity of the physiological status of the patients with concomitant midface trauma, and, based on the results obtained, develop an algorithm for treating patients within the framework of multi-stage surgical treatment tactic.

The research methods were based on the measurements of clinical and laboratory indexes, characterising the severity of the general state of the injured, a comparative biometric analysis of the values of these signs among the injured, depending on the nearest outcomes of the concomitant trauma in order to determine their significance in estimating the severity of the general state of the injured in dynamics, the course of the traumatic disease. and prognosis of the nearest outcomes of the concomitant trauma. The work uses laboratory, clinical, and instrumental research methods.

The main scientific results

1. The dynamics of the average values of the leukocyte intoxication index, the neutrophil-lymphocyte ratio, and the absolute number of lymphocytes and monocytes reflects the course of the traumatic disease and the severity of the physiological status of patients with a concomitant midface trauma. LII is an independent objective criterion reflecting the severity of the physiological status of the patients with a concomitant midface trauma and the severity of the course of the traumatic disease as a whole [35].

2. Taking into account the set of signs and time points studied by us, the third day after the occurrence of the injury is the most optimal point for predicting the immediate outcomes of the concomitant midface trauma. A method for predicting the immediate outcomes of a concomitant midface trauma has been developed. It has been

established that when a patient experiences cerebral edema, the likelihood of lethal outcome increases significantly [6, 36].

3. In the cohort of patients with a severe concomitant midface trauma the use of multi-stage surgical treatment tactic, taking into account the severity of the physiological status of the patients, led to a decrease in the frequency of infectious complications by 27%, non-infectious complications - by 5.8% and a decrease in mortality by 19%; in the cohort of patients with an extremely severe concomitant midface trauma - to a decrease in the frequency of infectious complications by 9.2%, non-infectious complications by 25.4% and a decrease in mortality by 17.9% [64].

4. During the testing and comparison of specific and non-specific methods for assessing the severity and predicting the outcomes of combined trauma, it was found that the accuracy of these methods and scales in the presence of severe traumatic brain injury is significantly reduced [62].

The main provisions submitted for defence

1. An objective method of assessing the severity of injuries and the physiological status of patients with a concomitant midface trauma is a mandatory tool in determining the scope of permissible and necessary surgical care and the timing of its provision.

2. The nature of morphological ratios of the main cells of the immune system, the severity of general intoxication of the body and infectious complications reflect the nature of the course of the traumatic disease. The leukocyte intoxication index is an objective criterion for assessing the severity of traumatic disease in dynamics.

3. The determinants of the severity of combined midface trauma for patients in the intensive care units in the third period of traumatic disease are: the presence of cardiovascular diseases in the anamnesis, the development of cerebral edema, the level of hemoglobin, the absolute number of lymphocytes and the severity of damage according to the MFS Injury Scale (MT).

4. The use of an algorithm for treating patients based on the key provisions of the multi-stage surgical treatment tactic taking into account the severity of the injury, the prognosis of immediate outcomes and the prognosis of the development of visceral infectious complications, contributes to increased efficiency and improved treatment results.

The degree of validity of the results of the study

In the course of the dissertation research, original methods and methods of collecting and subsequent processing of primary information were used in order to form a preliminary dataset for biometric analysis. The reliability of scientific statements, conclusions, and practical recommendations is ensured by compliance with the methodological systemic approach at all stages of the study and the use of adequate and modern methods of statistical data processing. Based on the collected clinical material, the issues of assessing the severity of the physiological status of the patients were studied mainly on the basis of objective laboratory indicators, which made it possible to develop and implement an algorithm for providing surgical care to patients with severe and extremely severe concomitant midface trauma.

Implementation of the results

The results of the dissertation research have been implemented in the practical activities of the First Neurosurgical Department (for patients with combined craniofacial trauma and damage to the organs of hearing and vision) of St Petersburg State Medical Institution 'Alexandrovskaya Hospital' and St Petersburg State Medical Institution 'Dzhanelidze Institute of Emergency Medicine'.

The results of the study have been used in the form of a lecture and are used in the educational process by the Department of Maxillofacial Surgery and Surgical Dentistry of St Petersburg University.

Approbation of the work

The main provisions of this dissertation were discussed at a meeting of the Department of Maxillofacial Surgery and Surgical Dentistry of St Petersburg University. The results of the work were reported at scientific conferences: the 5th All-Russian Congress with international participation 'Medical Care for Injuries. New in organisation and technology. Prospects of Import Substitution in Russia' (St Petersburg, 2020); All–Russian Conference on Natural Sciences and Humanities with international participation 'Science of St Petersburg University - 2020' (St Petersburg, 2020); All-Russian scientific and practical conference dedicated to the 100th anniversary of the birth of Professor V.A. Malyshev 'Topical Issues of Maxillofacial Surgery and Dentistry' (St Petersburg, 2022); All-Russian Interdepartmental Scientific and Practical Conference 'Modern Approaches to the Diagnosis and Treatment of Surgical Diseases, Injuries, and their Complications' (Moscow, 2022).

Publications

11 research papers have been published on the materials of the study, including 5 articles in peer-reviewed scientific journals recommended by the Higher Attestation Commission of the Russian Federation.

Personal contribution of the author

The author independently analysed the works of foreign and domestic authors, and defined the goal, objectives, methodology, design, and stages of the dissertation research. The researcher has developed and implemented an algorithm for collecting primary data and forming a preliminary representative dataset. The author was directly involved in the mathematical and statistical analysis of the research data. The author participated in the implementation of a complex of clinical, laboratory, and instrumental methods of examination.

In his co-authored scientific papers, the researcher has provided the main theoretical background for problem definition, design, clinical material collection, and drawing conclusions.

Scope and structure of the thesis

The thesis consists of 162 typewritten pages, including an introduction, a literature review, a chapter of materials and methods, a chapter of exploratory analysis, three chapters of own research, a conclusion, findings, practical recommendations, and a list of references including 101 Russian and 122 foreign sources.

CHAPTER 1.
CURRENT VIEWS ON THE PROBLEM OF ASSESSING THE SEVERITY OF PHYSIOLOGICAL STATUS AND INJURY IN PATIENTS WITH CONCOMITANT MIDFACE TRAUMA (LITERATURE REVIEW).

1.1. Signs of Dysfunction of Vital Organs and Body Systems in Patients with Concomitant Trauma

Special attention is paid to the search for signs indicating the severity of the violation of vital functions of the body when developing methods for assessing the severity of injury [33]. The higher the specificity of these signs to a certain nosology or damage, the higher the accuracy of the developed method. In the case of the concomitant midface trauma, the analysis of the special literature shows insufficient exploration of this topic [79].

The most common parameters used in assessing the severity of the physiological status of the patients is the level of blood pressure. According to A.N. Kolesnikov and other authors, the systolic blood pressure is a significant clinical parameter reflecting the degree of post-traumatic haemodynamic disorders and the likelihood of shock, especially at the prehospital stage [38], regardless of the localisation of the dominant injury [24, 32, 146, 173, 174, 183, 199].

According to S.D. Saverio et al., hypotension on admission to hospital with a systolic blood pressure of 90-100 mmHg against a background of blood loss and traumatic shock, with an Injury Severity Score of >16, can be considered a factor of adverse outcome [120].

Yu.V.Puras et al. similarly interpret episodes of arterial hypotension as an adverse outcome factor in patients with concomitant trauma [76]. Others have suggested that a rise in systolic blood pressure above 160 mmHg on admission to hospital has a high predictive value as a prognostic factor for death [201].

Another indicator of haemodynamics, often used in assessing the severity of the physiological status, is the heart rate (HR). E.J. Ley et al. found that the risk of death

in patients increases with a heart rate of ≤ 70 or ≥ 89 beats per minute at the time of admission to the clinic. The highest risk of death is observed with heart rate at the time of admission of <60 or ≥ 100 beats per minute [110].

Some researchers believe that heart rate alone is not a significant indicator of the severity of the patient's physiological status and the need for emergency surgical interventions when the patient is admitted to hospital [143].

G.P. Victorino et al. established that the relationship between heart rate and systolic blood pressure at the time of admission of the patient to hospital is not significant, and tachycardia is not a reliable sign of hypotension [219].

The haemoglobin level is a significant sign in assessing the severity of the physiological status of patients with severe blood loss. S.M. Alamshah et al. interpret a low haemoglobin level on admission of the patient to hospital as a valuable prognostic factor of an unfavourable outcome of a severe injury [136].

J.H. Holstein, et al. defined the haemoglobin level of 67 ± 29 g/l, the systolic blood pressure of 77 ± 27 mmHg, and the severity of the injury on the ISS scale at 35 ± 16 points on admission as factors of an unfavourable outcome for patients with severe concomitant trauma [146].

S. Majercik et al. indicate the importance of the red blood cell distribution index - RDW (Red Cell Distribution Width) in predicting the lethal outcome of a severe injury. The index, according to the authors, makes it possible to make an accurate prediction of the 30-day mortality in male patients, and the annual mortality in male and female patients [182].

The researchers discuss the significance of blood gas composition indicators in assessing the severity of the physiological status of patients with concomitant trauma. According to T.M. Dumont et al., an increase in the partial pressure of blood carbon dioxide (pCO2) >45 mmHg (hypercapnia) or its decrease <35 mmHg (hypocapnia) in patients with severe concomitant trauma at the time of admission to hospital increases the probability of death [151]. According to other data, the gas composition of blood is not a significant factor in predicting the fatal outcome in patients with concomitant trauma [144].

B. indicate no correlation between the Glasgow Coma Scale (GCS) score and blood gas values (pH, pO2, pCO2, HCO3- bicarbonate andSO2 saturation) during the first 4 hours after admission in a patient with severe concomitant trauma. According to the authors, there was also no significant difference in the average values of blood gas composition in patients with favourable and unfavourable outcomes [132].

Redistributive leucocytosis often occurs after injury and is associated with significant physiological stress. It occurs as a result of the demargination of leukocytes from the walls of blood vessels under the action of catecholamines [125, 157, 180].

When examining the number of leukocytes in the patients at the time of admission to hospital, D.C. Chang et al. found that there was a connection between the severity of injuries on the ISS >15 scale and an increase in the number of leukocytes to 11,9x10 ^{9}/l, as well as between the sum of scores on the scale of GCS ≤8 and leukocytosis at the level of 13.0 x10 ^{9}/l [137].

Claudia A. Santucci et al. when comparing the number of leukocytes in patients with severe trauma and in patients with mild and moderate trauma at the time of admission to hospital, found that the number of leukocytes in the two groups significantly differed. The authors established weak direct correlation (coefficient to correlation = 0.37) of the severity of injuries on the ISS scale and the number of leukocytes on admission [188].

In the study by S. Lam et al., comparing the total number of leukocytes and their differential counting, as well as the size of blood neutrophils in patients with favourable and lethal outcomes within seven days after injury, found that the size of neutrophils upon admission to hospital is a significant prognostic factor of seven-day mortality. The total number of leukocytes and their differential counting had no prognostic value [125].

There is some literature indicating the importance of neutrophil to lymphocyte ratios, measured at the time of admission, in predicting adverse outcome of concomitant trauma [195], including concomitant TBI [165].

To describe coagulopathy, hypothermia, and metabolic acidosis, the term 'triad of death' is often used in foreign scientific literature. These signs are associated with

impaired tissue perfusion, haemostatic disorders, and the development of multiple organ failure [74, 134].

According to M.G. Balverde et al., the 'triad of death' syndrome can be classified as an independent adverse outcome factor for combined trauma, and is characteristic of injuries with an ISS score of >30-35. The 'triad of death' syndrome includes coagulopathy (international normalized ratio (INR)>1.5), hypothermia (temperature <35 ° C) and metabolic acidosis (pH <7.2) [178].

B. Mitra et al. found that the probability of a fatal outcome in patients with the 'triad of death' is 48%, and with INR >3.2 - 100% [211].

Most researchers determine the level of coagulopathy, which can be used as an independent factor of an unfavourable outcome of a concomitant injury, by the INR indicator. According to M.E. Kutcher et al., this indicator should exceed 1.3 [114], and according to other data - 1.5 [111, 122].

M. Kapan and other researchers have identified hypothermia below 35° on admission to the hospital, as an independent factor of the unfavourable outcome of a concomitant injury [138, 199, 202]. According to other researchers, hypothermia cannot be taken as an independent factor of an unfavourable outcome of a concomitant injury [138, 191], since it is only a manifestation of other post-traumatic disorders, such as coagulopathy, acidosis, or severe blood loss [139].

Blood lactate concentration reflects the level of oxygen deprivation of tissues, acidosis, and the acid-base state of the body. Hyperlactemia is one of the prognostic factors of an unfavourable outcome of a concomitant injury [176, 205].

Normally, the blood lactate level does not exceed 1 mmol/L. The lowest level of hyperlactemia, which can be taken as an indicator of oxygen deprivation of tissues, acidosis, and severe disorders of the acid-base state of the body, is 2 mmol/L [175], or according to other data 4.1 mmol/L [74].

S.M. Alamshah et al. defined metabolic acidosis with a blood pH <7.2 was determined as an independent factor of an unfavourable outcome of injury [136]. M.T. Gokdemir et al. Gokdemir et al. note a correlation between total plasma oxidative status in severely injured patients and mortality and injury severity on the ISS and Revised

Trauma Scale - RTS. The authors suggest using this parameter as an early biomarker of oxidative stress to control the severity of patients with multiple trauma in its acute period [185].

According to E. Fitzsullivan et al., the level of blood plasma bicarbonate HCO3- has a strong positive correlation with the level of plasma base deficiency, both at the time of admission hospital (r =0.80) and at the entire stage of hospital treatment (r =0.85). Both indicators more accurately reflect the level of metabolic acidosis than the pH or blood lactate level. The authors also note the presence of a significant difference in the average indicators of deficiency of bases and bicarbonate HCO3- in patients with favourable and unfavourable outcomes (2.5 and 5.2; 17.7 and 19.8 mmol/L, respectively) [189].

Plasma potassium and sodium levels are often used to describe and assess water-electrolyte imbalance. In their study, V. Morell et al. found that hypokalemia with a potassium level (K+) <3.6 mmol/L on admission correlated with the severity of injuries on the ISS scale and the duration of hospital stay of the patients [161].

Investigation of potassium (K+) levels on admission in patients with concomitant trauma in the work of A.L. Beal et al. showed that hypokalaemia (<3.6 mmol/L) was more common in patients with TBI. In patients with hypokalemia, the sum of points on the GCS was lower, and the sum of points on the ISS scale was higher than in patients with normal potassium levels. The need for artificial lung ventilation (ALV), the duration of stay in the intensive care unit (ICU) and the duration of hospital stay were greater in patients with hypokalemia. The authors also noted that the sum of the scores on GCS in patients with potassium levels < 3.1 mmol/L was lower than in patients with potassium levels in the range of 3.1-3.6 mmol/L [148].

S. Pomeranz et al., when comparing the level of potassium on admission to hospital in the group of patients with isolated severe TBI (≤ 7 points according to GCS) and the group of patients with concomitant trauma, but without TBI, found that the level of blood potassium in the patients of the first group was significantly lower than in the patients of the second group. The average potassium level in the patients of the first and second groups was 3.1±0.4 mmol/L and 3.5±1.1 mmol/L, respectively.

According to the authors, this difference is due to large catecholamine emissions in severe TBI with subsequent stimulation of sodium-potassium pumps [170].

A. Vedantam et al. when studying the blood sodium level (Na+) in the first week after admission in patients with severe TBI, found that hypernatremia (Na+ >150 mmol/L) is associated with the likelihood of acute renal failure and death [218]. Other researchers have also found that hypernatremia (Na+ = 148-152 mmol/L) in patients with severe TBI (≤ 8 points according to GCS) is associated with an increased probability of an unfavourable outcome of the injury [206]. Similar results were obtained by Hoffman H. et al., who found that hypernatremia in patients with severe TBI is associated with an increase in the probability of death and the duration of hospital stay [145, 147].

In a study of factors associated with lethal outcome in patients with grade III traumatic shock, Stukanov et al. found the following parameters to be associated: hypothermia (temperature <35.7°C), increased lactate concentration in venous blood to 4.1 mmol/L, venous blood pH to 7.19, ionised calcium in venous blood to 0.3 mmol/L and activated partial thromboplastin time to 59 sec. [74].

According to G.A. Alexiou, an increase in blood sugar levels is often found in patients with concomitant trauma [116]. J. Kreutziger et al. found that the blood sugar level on admission to hospital of >10 mmol/L or <2.8 is more common in patients with traumatic shock [115].

In various publications, researchers have assessed the importance of blood sugar levels in predicting the outcome of injury. According to some researchers, the blood sugar level >8.8 mmol/L is a significant prognostic factor of an unfavourable outcome of TBI [184]. According to other data, blood glucose level is not a significant factor in predicting an unfavourable outcome of TBI [114].

F. Salehpour et al. indicate that the blood sugar level is not a significant factor in predicting an unfavourable outcome of severe TBI. The difference in the average values of blood glucose levels in patients with favourable and unfavourable outcomes was not significant (10.3±2.9 and 10.4±4.2 mmol/L, respectively). The authors also

did not reveal a significant correlation between glucose levels and the sum of scores on the GCS [119].

Analysing the above research results of foreign and domestic authors, we can talk about a variety of signs of post-traumatic disorders of the functions of organs and body systems, which is associated with the complexity and nature of their interaction in response to traumatic effects.

It should be emphasised that most researchers have studied these signs in trauma patients, irrespective of their features and localisation, including the location of the leading injury in terms of severity. Most of these studies were carried out at a specific time point (most often at the time of admission to the clinic), or at a short time interval (up to 3 days).

Thus, an important and, at the same time, unsolved problem of an objective assessment of the severity of a concomitant midface trauma is the issue of identifying physiological signs reflecting the severity of the physiological status of the patients in the the course of traumatic disease (TB).

1.2. Objective Assessment of the Severity and Prediction of the Immediate Outcomes of Injuries

The severity of injury is a complex concept that includes the severity of injuries and the severity of the physiological status. The severity of the injuries is a relatively stable indicator reflecting the morphological component of the injury (the result of the interaction of morphological structures of the body with the damaging agent). It depends on the localisation, the extent of anatomical damage, and the functional significance of the damaged organ [20, 32, 47, 49, 50, 57, 65, 87, 93].

The severity of the physiological status reflects the functional component of the injury and depends on the severity of functional disorders, the time from the moment of injury, and the initial state and reactivity of the body. The severity of the physiological status is a labile indicator and it can change at different stages of medical care, depending on its scope and quality [20, 32, 47, 49, 50, 57, 65, 87, 93]. The severity

of the physiological status and the severity of the damage are interrelated, but not interchangeable.

Assessment of the severity of injuries serves to address the following tasks:

1. Classification of injuries;
2. Sorting of patients;
3. Predicting the outcome of injury and the likelihood of complications [75];
4. Determination of the composition of the team of specialists involved in the process of diagnosis and treatment, and the priority of providing assistance to patients [80];
5. Determination of the scope of diagnostic tests [81];
6. Comparison and analysis of the quality of medical care provided and identification of its shortcomings [81];
7. Optimisation of treatment tactic at different stages of medical care;
8. Standardisation and objectification of the approach to solving various tasks in the provision of medical care and reducing the likelihood of errors in diagnosis and treatment [81].

Prior to the development and implementation of modern systems of objective assessment of the severity of injuries in clinical practice, descriptive methods were traditionally used to indicate the severity of injury [30, 34].

Over the history of the study of this problem since the early 1970s, domestic and foreign specialists have developed and tested dozens of methods and scales [33, 62, 80]. A large number of proposed methods indicate the complexity and importance of this problem and the lack of a single and generally accepted opinion on its solution, both in world and domestic medicine [31].

The lack of a unified system for assessing the severity of injuries makes it difficult to compare the effectiveness of various methods of treating patients, including the level of mortality and the risk of complications with the same severity of injuries [62, 83, 84, 85, 171, 210].

The need for a universal and unified system for assessing the severity of injuries is obvious and does not cause disagreement among specialists. However, the

development and implementation of a unified method for assessing the severity of injury proved to be a difficult task.

The human body is a very complex system. The variety of injuries and disorders occurring in the body after injury make it difficult to create a universal method [79]. It is debatable which parameters most accurately reflect the severity of the physiological status of the patient and should be taken as the basis of a universal method.

The development of a unified method for assessing the severity of injuries is also hampered by differences in equipment in hospitals and constant changes in the care of the injured, due to the introduction of new technologies in the treatment process [81]. The accuracy of the methods developed in some institutions may decrease when they are used in other institutions with a lower level of quality of medical care [79].

1.2.1. Methods for Assessing Severity and Predicting the Immediate Outcome of Injuries

Depending on the characteristics of the parameters used in the assessment, the methods of assessing severity can be divided into 3 groups:

1. Anatomical methods - based on the assessment of the severity of morphological disorders of various tissues and organs.

2. Physiological methods - based on the assessment of physiological parameters reflecting the severity of the physiological status of the patient.

3. Combined methods - include assessment of both morphological disorders of tissues and organs, and the severity of the physiological status of the patient [52, 65, 75, 83, 99].

The methods for assessing the severity of injuries vary depending on the task they solve. They can also be divided into general and specific methods of assessing severity. The general methods apply to all types of injuries or diseases, regardless of their localisation and nature. Specific methods are used in the treatment of certain diseases or in case of damage to a certain organ or organs and tissues of one anatomical

area. A brief description of the most clinically known scales and methods for assessing the severity and prognosis of injury outcomes will be presented below.

1.2.1.1. Anatomical Methods for Assessing the Severity of Injuries

Among the first methods of assessing the severity of injuries was the Abbreviated Injury Scale - AIS, developed in the USA in 1969. The scale is based on a score assessment of the severity of the most critical injury [124, 149, 181]. Since that time, the scale has been revised and supplemented 8 times and the last one was in 2015 [107].

Since the developers of the AIS scale did not try to solve a medical problem, but sought to create a system for determining insurance payments depending on injuries sustained in car accidents, the AIS scale in its initial form was not adapted for use in clinical practice. Due to the fact that the AIS injury severity scale is scored on the basis of the number of points of one most severe injury, it is considered unsuitable for use with multiple and concomitant injuries [200]. Nevertheless, this scale laid the foundation for the development of modern methods for assessing the severity of injuries and the introduction of a point-based severity assessment instead of a descriptive one.

S.P. Baker et al. in 1974 proposed a scale of injury severity - ISS (Injury severity score), created on the basis of the AIS scale. In the ISS scale, the authors used the damage codes proposed in the AIS scale. The severity of injuries on the ISS scale includes the sum of the squares of the codes of the 3 most severe injuries in 3 different anatomical areas [203].

Thus, the sum of points on the ISS scale varies from 1 to 75 points. The authors proposed the following interpretation of the assessment: 1-8 points - light injuries; 9-15 points - moderate injuries; 16-24 - serious injuries with a high probability of survival; 25-49 - severe injuries with a high probability of death; 50-74 - critical injuries; 75 points – injuries incompatible with life. If an injury is coded at 6 on the

AIS scale, it is considered incompatible with life and automatically coded at 75 on the ISS scale [203].

The ISS is by far the most widely used and discussed scientific method for assessing injury severity. It is used as a standard for the classification of injuries in many countries, including the USA, Australia, and most European countries [197].

However, the ISS method has a number of disadvantages. P.A. Seliverstov et al. indicates that the ISS scale underestimates the importance of severe TBI in determining the outcome of a combined injury. The authors also note that the number of points assigned to each injury on this scale does not always correspond to their value in determining the outcome of the injury [79].

The next drawback of the ISS method is related to the method of assessing the severity of multiple injuries. The ISS scale takes into account only one most severe injury within one anatomical area. This means that if there are several severe injuries in one anatomical area, only the most significant one is taken into account, and the role of other injuries in determining the outcome of the injury is not evaluated. At the same time, other, lighter injuries occurring in other anatomical areas are assessed, even though their contribution to determining the outcome of the injury is clearly less [38, 166].

To address this problem, T. Osler et al. proposed using a new injury severity scale - NISS (New Injury Severity Score), which is essentially a modification of the ISS scale. When assessing the severity of injuries on this scale, the three most severe injuries are taken into account, regardless of their localisation [166].

Another modification of the ISS scale was presented by W.S. Copes et al. in 1990. Anatomic Profile Score - APS takes into account three injuries with a severity> of 3 points on the AIS scale. One injury in the head and spinal cord area, one in the chest and neck area, and one in other anatomical areas are taken into account. The calculation on this scale is carried out using the logistic regression equation [179]. Due to the complexity of the calculation, this scale is not widely used among specialists.

In an attempt to create a unified international scale for assessing the severity of injuries, T. Osler et al. developed a method for assessing the severity of injuries based

on the International Classification of Diseases 9 (ICD-9) - ICISS-9 (International Classification of Disease-9 (ICD-9) based Injury Severity Score). The severity of the injury on this scale is assessed using the SRR (survival risk ratios) survival coefficient calculated for each specific injury [149].

According to the authors, the accuracy of this method is due to the fact that it was developed on an empirical basis, with the inclusion of a large number of patients (in ICISS-9 = 300,000 patients) and with the calculation of the probability of a fatal outcome for each injury in a retrospective way [149].

The ability to calculate the survival rate for each injury reflected in the ICD-9 raises questions, since most often these injuries, including injuries leading to a lethal outcome, occur in practice in a combined form [79].

Due to the fact that the International Classification of Diseases (ICD) is periodically revised, as well as the fact that the quality of medical care is changing, this method requires periodic revision [81].

The level of medical care differs in different states and, accordingly, the probability of mortality for certain injuries may vary depending on the locality, which calls into question the accuracy and universality of this method.

T. Osler et al. in 2008 presented a model for predicting the probability of a fatal outcome of patients - TMPM (Trauma Mortality Prediction Model). The model is based on the assessment of the 5 most severe injuries, regardless of their localisation, using the AIS scale followed by mathematical modeling [106].

We consider the Military Field Surgery (MFS) injury severity scale in the combined methods section, together with other MFS severity scales, as it is part of a combined severity assessment system.

1.2.1.2. Physiological Methods for Assessing the Severity of Injuries

Physiological methods for assessing the severity of the physiological status of the injured person are based on the following principle: the severity of the

physiological status of the injured person can be measured by the degree of deviation from the normal physiological indicators after injury.

To assess the severity of TBI and the level of consciousness of the patient, the Glasgow Coma Scale (GCS) is widely used. The parameters evaluated on this scale are: motor reaction, speech response, and eye opening. The number of points received varies in the range of 3-15. The higher the score, the less severe the trauma and the less pronounced the impairment of consciousness [33, 194].

Despite the high level of subjectivity of the assessment method on this scale, it has found wide application, due to its simplicity and convenience. Literature data indicate high levels of sensitivity (79-97%) and specificity (84-97%) of this scale, both for assessing the severity of TBI and for predicting the fatal outcome in severe TBI [2, 76, 173].

H.R. Champion et al. in 1980 presented a scale for sorting patients - TS (Triage Score). The sorting of the patients, according to this scale, is based on the assessment of the following 3 parameters: chest excursion during breathing, capillary filling, and the level of consciousness according to the scale. The scale allows for pre-hospital care to determine where to take the patient, to a specialised or general hospital [113].

In 1981, the first modified version of the scale for sorting patients was proposed under the name 'Trauma Score'. In addition to the level of consciousness in the GCS and the degree of capillary filling, the scale also takes into account the level of systolic blood pressure and respiratory rate, and its nature - with or without the involvement of auxiliary muscles in the breathing process [212].

The work was continued and in 1989 a revised scale of injury severity appeared - RTS (Revised Trauma Score). The method is based on the evaluation of 3 parameters: the sum of the scores on the GCS, systolic blood pressure, and respiratory rate. In this scale, there is no need to assess the level of capillary filling or the participation of auxiliary muscles in the breathing process, which are difficult to assess in the field. The authors proposed two variants of the new scale: a simplified sorting variant - T-RTS (Triage Revised Trauma Score) - for use at the prehospital stage and a basic version of RTS - for assessing the outcome of injury and its severity. The triage version is based

on the summation of the scores of the values obtained. The main variant is calculated using the logistic regression equation and is often used to estimate the probability of survival [105].

One of the most common non-specific methods of assessing the severity of the physiological status in clinical practice worldwide, based on the assessment of physiological indicators, are the APACHE II scale (Acute Physiology and Chronic Health Evaluation II) and the simplified scale of acute physiological disorders - SAPS II (simplified acute physiology score II) [164].

There are four variants of the APACHE scale. The most well-known of them was the second version - APACHE II. The second revised version of the APACHE II scale includes 12 parameters: GCS value, heart rate, blood pressure, respiratory rate, rectal temperature, hematocrit, partial pressure of oxygen in arterial blood (Pa02), white blood cell count, sodium, potassium, plasma creatinine, and arterial pH. Points are also added to the total score for the need for surgical interventions, age, and the presence of chronic diseases [112].

In 1993, a simplified assessment scale of acute physiological disorders (SAPS II) was presented for patients staying in the ICU. The SAPS II scale includes 17 variables: 12 physiological indicators, age, type of hospitalisation (planned surgical, unplanned surgical, or non-surgical) and three categorical variables associated with concomitant diseases (acquired immunodeficiency syndrome, metastatic cancer, and blood cancer) [120].

According to V.V. Aghajanian and others, the use of APACHE and SAPS limits the inclusion of parameters such as blood Na+, K+ concentration, venous blood plasma bicarbonates, and arterial gas values, as determining these values over time is not available in many health institutions [1, 41].

To assess the severity of multiple organ failure and the likelihood of death in the ICU, a scale of sequential assessment of organ dysfunction - SOFA (Sequential Organ Failure Assessment) is used. The scale was first introduced in 1996 under the name 'Sepsis-related Organ Failure Assessment', but was subsequently renamed after its effectiveness was established in the absence of sepsis. SOFA assesses respiratory

function (arterial partial oxygen pressure (PO2) to inspiratory oxygen fraction (FiO2)), coagulation (platelet count), liver function (total bilirubin), cardiovascular function (hypotension), central nervous system (GCS value) and renal function (creatinine or diuresis). Each parameter is evaluated in points, from 1 to 4. Based on the sum of the scores of all indicators, the probability of survival of the patient is determined [208].

Researchers' opinions on the effectiveness of universal and non-specific methods for assessing the severity of the physiological status differ. Some researchers report the effectiveness of methods such as SOFA, APACHE II and SAPS II [94, 129, 173, 177], while others point to their inaccuracy when comparing the results of use for patients with somatic pathologies and for patients with severe trauma [187].

1.2.1.3. Combined Methods for Assessing the Severity of Injuries

Combined methods take into account both the degree of deviation of physiological parameters from the norm and the severity of morphological disorders due to the trauma. In this regard, combined methods, unlike many physiological methods, are characterised by specificity.

Among the first combined methods is that of Yu. N. Tsibin. This method was developed in the late 70s on the basis of Dzhanelidze Research Institute of Emergency Medicine. The method allows to predict the time in hours from the moment of injury to the onset of haemodynamic stabilisation and thereby assess the probability of survival of the patient. To predict the outcome of an injury, the method uses the following parameters: age, pulse rate, systolic blood pressure, and the sum of severity of injuries. The assessment is based on the logistic regression equation [96, 97].

Some authors point out the limitations of this method due to the fact that it does not take into account the severity of the trauma, which is a frequent component of a co-injury [60], the level of consciousness of the patient [52], and such severe injuries as cerebral compression and spinal cord injury, which, in some cases, determine the outcome of the injury [81].

H.J. Oestern et al. in 1985 presented a scale for assessing the severity of polytrauma - PTS (Polytrauma Score, Hannover). The scale assesses the severity of injuries to five anatomical areas of the body and the age of the patient. A modified version of the scale was also presented, which takes into account the sum of points on the GCS, the level of base deficiency, and the Horovitz coefficient: PO2/FiO2.2. H.J. Oestern et al. suggest classifying polytrauma by severity based on this scale into four degrees: first degree of severity (up to 20 points), second degree (20-34 points), third degree (35-48 points), and fourth degree (>48 points). The predicted mortality rate for each degree is <10%, <25%, <50%, and <75%, respectively [124].

C.R. Boyd et al. proposed a method of assessing the severity of trauma and injury - TRISS (Trauma and Injury Severity Score) to assess the severity of the injury and the physiological status of the patients. The TRISS method is based on two previously created scales for assessing the severity of damage - ISS and RTS. The method also takes into account the influence of the age of the patients (≥55 years) on the severity of their physiological status [118].

The second revised classification of the severity of injuries - RISC II (Revised Injury Severity Classification II) for predicting the probability of death in patients with concomitant trauma was proposed by R. Lefering et al. The RISC II scale includes the following parameters: the severity of the two most severe injuries and head injuries on the AIS scale, age, gender, assessment of motor reaction on the scale, pupil reaction and size, the nature of the injury (blunt or penetrating), the sum of points on the scale of the American Society of Anesthesiologists - ASA, the need for cardiopulmonary resuscitation, systolic blood pressure, INR, and deficiency of blood bases and haemoglobin [215].

Separate inclusion of the severity of head injuries and the severity of injuries to other anatomical areas in the RISC II prognostic model contributed to its prognostic power [215].

A Severity Characterisation of Trauma (ASCOT) scale was introduced in 1990. To describe the severity of damage, the scale uses the codes described in the AIS scale (updated in 1985). The scale also includes the following physiological parameters: the

level of consciousness according to the GCS upon admission to the ICU, the patient's age, systolic blood pressure, and respiratory rate [104].

Among domestic methods of assessing injury severity, the military field surgery (MFS) method of objective assessment of injury severity became widely used. This method was developed in 1992 and includes several scales, based on both anatomical and physiological principles and adapted to meet specific clinical needs. The method includes: scales for assessment of the severity of injuries in three versions: for gunshot wounds, for non-gunshot wounds, and for mechanical injuries; the MFS triage scale; scales for assessment of the physiological status of the injured or wounded person in three versions: on admission, for dynamic follow-up in medium-level institutions, and in specialised centres; scales for prediction and diagnosis of fat embolism; a scale for diagnosis of cardiac contusion; a surgical tactic scale; and an endovideosurgical scale. The authors also presented qualitative equivalents of scores on scales; the predicted frequency of complications; the probability of death and the duration of disability [20, 26].

The MFS Injury Scale (mechanical injury) includes 84 of the most common injuries in clinical practice in six anatomical areas (head, chest, spine, abdomen, pelvis, and limbs) with severity codes from 0.05 to 19. The severity of the injuries includes the sum of all existing injuries in all anatomical areas, which undoubtedly increases the accuracy of assessment in multiple and concomitant injuries [26].

The MFS Scale - admission status scale is used to assess the severity of the physiological status of the patient upon admission to hospital. The scale includes 12 physiological parameters: the colour of the skin, the nature of external respiration, auscultative changes in the lungs, reaction to pain, speech contact, systolic blood pressure, pulse rate, pulse pattern, pupillary or corneal reflexes, pupil size, approximate amount of blood loss, and intestinal peristalsis noises [20].

According to A. N. Tulupova et al., the VPH method was developed on the basis of a clinical material of a sample population, the main component of which were healthy persons (service men) of a limited age category, and therefore this method does

not always give an accurate assessment of the severity of injuries in persons of other age groups suffering from concomitant diseases [69].

According to A.V. Semenova et al., the following points can be attributed to the disadvantage of the method of assessing the severity of VPH injuries: the sign used in different scales is encoded with different values, which can lead to evaluation errors; the level of consciousness of the patient is not evaluated upon admission; a large number of parameters used makes the process of assessing the severity of injuries difficult and takes a lot of time; the use of subjective parameters, such as the noise of intestinal peristalsis, the approximate amount of blood loss, and the nature of external respiration [81].

1.2.2. Analysis of the Validity of Methods for Assessing Severity and Prognosis of Immediate Trauma Outcomes

Judging by the number of scientific publications, the methods described above are the most common in clinical practice and the most discussed in the scientific field. But the question of which of the methods is the most effective and accurate is a very controversial issue. The analysis of special literature indicates the presence of many domestic and foreign publications devoted to the study of the effectiveness of various methods [22, 75, 102, 109, 126, 127, 128, 172, 192, 200]. Below we will present a small part of the published scientific material on the study of this problem.

The most common parameter used in evaluating the effectiveness of severity assessment methods is the accuracy of predicting the probability of a lethal outcome. Most researchers conduct an assessment by constructing a ROC curve (Receiver Operating Characteristic), followed by measuring the area under the curve and evaluating the sensitivity and specificity of the method. The predicted and actual deaths of the patients are also compared. Table 1 presents the results of comparative studies of the prognostic value of various methods of assessing severity.

Table 1. The results of scientific research on the comparative analysis of the accuracy of some methods of assessing the severity of predicting the fatal outcome of injuries

Studies	Compared methods	Identified results
[158, 162, 193]	NISS and ISS	NISS is superior to ISS
[207]	APACHE II, NISS, and ISS	APACHE II is superior to NISS and ISS
[130]	APACHE II and GCS	APACHE II is superior to GCS
[131]	APACHE II and SOFA	Scales equal in accuracy
[67]	APACHE II and ISS	ISS is superior to APACHE II
[68]	APACHE II and ISS	Scales equal in accuracy
[177]	SAPS II and SOFA	SAPS II is superior to SOFA
[131, 153, 196, 213]	TRISS APACHE II and SOFA	Scales equal in accuracy
[103, 155]	TMPM, ISS, NISS, AIS, and ICISS	TMPM is superior to the rest
[150]	ASCOT and TRISS	ASCOT surpasses TRISS
[209]	ASCOT and TRISS	Scales equal in accuracy
[9, 67]	ISS, APACHE II, MFS-I(injury), and MFS-CA (physiological status on admission)	ISS and APACHE II are superior to MFS-I and MFS-CA
[167]	RISC II and TRISS	RISC II is superior to TRISS
[102]	ISS, APS, NISS, and ICISS-9	Scales equal in accuracy
[149]	ICISS-9 and ISS	ICISS-9 is superior to ISS
[200]	ICISS-9, ISS, and TRISS	ICISS-9 is superior to ISS and TRISS
[127]	APACHE II and TRISS	APACHE II is inferior to TRISS
[109]	APACHE II and SAPS II	Scales equal in accuracy
[33, 59]	ISS and MFS-I (MT - mechanical trauma)	Scales equal in accuracy
[156]	APACHE III and SAPS II	Scales equal in accuracy
[22]	ASCOT and SAPS II	Scales not suitable for this purpose

The data in Table 1 show that the published research results are extremely contradictory. The superiority of one method, revealed in one study, is rejected in another. When analysing scientific publications comparing the ICISS, NISS, and ISS

scales on the accuracy of predicting the fatal outcome in patients with combined trauma, H. Tohira et al. obtained extremely contradictory results [193].

The clinical material used in the development of non-specific methods includes both trauma patients and patients with general somatic diseases. For example, about 30% of the clinical material used in developing the APACHE II scale relates to trauma patients, and the bulk of the clinical material relates to patients with somatic diseases [112].

Some authors note that the use of a combination of trauma-specific and non-specific methods for assessing the severity of the physiological status can increase the accuracy of predicting the fatal outcome of patients [177], but non-specific methods do not take into account differences in the course of decompensated forms of somatic diseases and traumatic disease.

S.K. Park et al. when studying the effectiveness of the APACHE II and SAPS II scales in predicting mortality in patients with severe TBI revealed that the mortality predicted by both methods (APACHE II= 37.7%; SAPS II= 38.4%) is almost 12% higher than the actual mortality (24.8%). The authors identify the need for a new method of predicting the outcome of a traumatic brain injury, taking into account the severity of brain dysfunction [109].

Some researchers point to differences in the course of trauma illness in concomitant injuries depending on the localisation of the leading injury and to a decrease in the accuracy of common trauma-specific methods, such as RISC II, in patients with severe traumatic brain injury [217].

Thus, according to the literature review, a large number of specific and non-specific methods have been proposed to assess the severity and predict outcomes of injuries. Nevertheless, the results of the studies during testing and comparison turned out to be ambiguous and often mutually exclusive. Researchers have often observed a decrease in the accuracy of these methods and scales in patients with severe TBI, and the problem of predicting the immediate outcomes of combined midface trauma based on specific clinical material has not been studied.

1.3. Current Status of the Problem of Treating Patients with Concomitant Midface Trauma

The analysis of special scientific literature available to us shows that most of the studies devoted to the topic of midface injury were aimed at studying the functional and aesthetic consequences of isolated injuries. The problem of concomitant midface trauma and craniofacial trauma as a whole has received much less attention.

A significant part of the work on optimising treatment tactic in patients with concomitant midface trauma was carried out on the basis of the departments of Maxillofacial Surgery and Surgical Dentistry of Kirov Military Medical Academy and St Petersburg University. It included the development and testing of the concept of multi-stage surgical treatment (MST) and the development of devices for external fixation of fractures of the maxillofacial bones.

I.M. Belous studied the possibility of using the MFS method of severity assessment in the treatment of patients with a concomitant maxillofacial trauma. The author also presented a scale for assessing the severity of maxillofacial injury 'MFS - MFI (MT - mechanical injury) based on the MFS method. According to the author, the periods of fixation of fractures are determined depending on the degree of compensation for the physiological status of the patient. The author noted the positive results of applying the MFS method in the organisation of treatment tactic for patients, such as a 2.37% reduction in mortality, a 2-fold reduction in complication rates, and a 2-fold reduction in length of stay in the ICU and in hospital in general) [10].

M.O. Danilevich proposed to use the method of the revised trauma score - RTS to assess the severity of craniofacial trauma. The author points out the simplicity and convenience of using this method, as well as its superiority in accuracy compared to the GCS. The accuracy of prediction of the RTS method, according to the author, is 85% [28].

According to D.Yu. Madai et al., the use of tactic based on the MFS method of objective assessment of trauma severety and the concept of traumatic illness has reduced mortality in patients with concomitant craniofacial trauma by 5.4 times, the

number of complications in this group of patients - by 1.4 times, and the length of stay in the ICU - by 1.6 times [58, 61, 64, 90].

K.P. Golovko et al. established that diagnostics and surgical tactic based on the application of the MFS method of objective assessment of injury severity, endovideosurgery, and minimally invasive extrafacial osteosynthesis in treatment of patients with combined traumas of maxillofacial region, have contributed to the 61% decrease of rates of purulent-septic complications, 37.5% decrease of lethality, and 1.8 times (from 6.9±0.4 to 4.1±0.7 days) decrease of ICU-treatment duration [24, 56].

From the literature review data, it can be seen that the amount of work done to optimise treatment tactic for patients with concomitant midface trauma based on objective assessment of injury severity is limited. Most researchers use the MFS injury severity assessment method to assess the severity of injuries. In addition, in previous studies, insufficient attention was paid to the problem of treating patients with extremely severe concomitant midface trauma. The issue of the indications for individual surgical interventions within the framework of MST tactic has also not been studied.

CHAPTER 2.
MATERIALS AND METHODS OF RESEARCH

2.1. Research material

The study was conducted at the clinical facility of the Department of Maxillofacial Surgery and Surgical Dentistry of St Petersburg University - the 1st Neurosurgical Department (for patients with concomitant craniofacial trauma and hearing and vision injuries), and the Intensive Care Unit No 2 and the Concomitant Trauma Department of St Petersburg Aleksandrovskaya Hospital. The study is based on the data of clinical material presented by 111 patients with concomitant midface trauma. The criteria for inclusion in the study were: concomitant midface injury, severity of injuries ≥ 1 point on the MFS - I (MT) scale (severe or extremely severe), duration of hospital treatment> of 3 days (patients who died in the first 3 days after the injury were excluded from the study).

2.1.1. General characteristics of patients with combined midface trauma

The proportion of male patients is 74.8% (n=83) of all patients; the proportion of female patients is 25.2% (n=28). The age of the patients varies from 18 to 96 years. The main proportion of patients is represented by young people (18-44 years old) - 55% (n=61). Middle-aged patients (45-59 years old) comprised 19.8% (n=22) of the total number; elderly patients (60-74 years old) - 16.2% (n=18); old patients (75-89 years old) - 8.1% (n=9); long-lived patients (over 90 years old) - 0.9% (n=1). The average age of all the patients was 46.9±18.5 years. The age distribution of the patients is shown in detail in Figure 1.

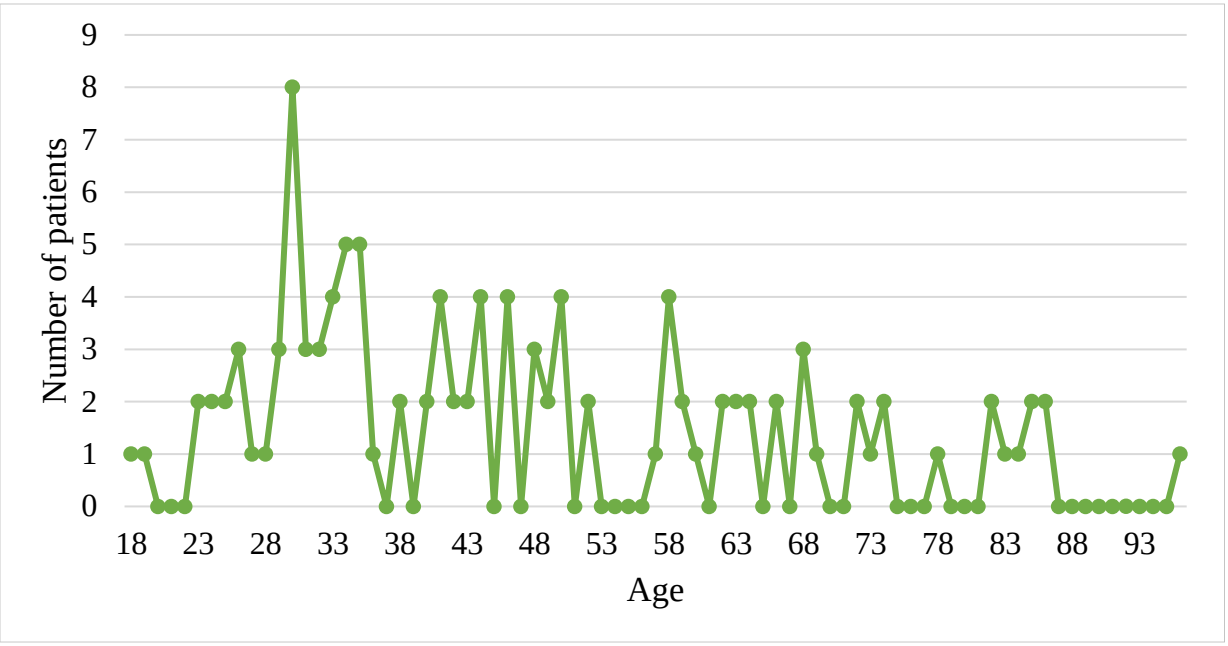


Figure1. Distribution of the studied patients by age.

According to the conclusion of the staff therapist, in the group of 95 patients, 52 patients (54.7%) suffered from concomitant diseases. Diseases of the cardiovascular system were diagnosed in 44 (46.3%) patients; nervous system diseases in 20 (21.1%) patients; urinary system diseases - in 8 (8.4%); endocrine system diseases - in 7 (7.4%); digestive system diseases - in 5 (5.3%); and respiratory diseases - in 4 (4.2%) patients.

Assaults with the use of physical force were the most common cause of injuries and occurred in 38 (34.2%) patients. In second place is the car accident, with 25 (22.5%) patients. Fall-related injury was observed in 24 (21.6%) patients. 14 (12.6%) of the patients fell from heights over 3 metres and 10 (9%) fell from their own height. Two (1.8%) patients were injured with traumatic weapons. The mechanism of injury could not be established in 22 (19.8%) patients. The mechanisms of injury occurrence are presented in Table 2.

Table 2. Mechanisms of occurrence of concomitant midface injury

Injury mechanism	Number of patients, n = 111	
	absolute number	%
Assault with the use of physical force	38	34.2
Traffic accident	25	22.5
Falling from a height of over 3 metres	14	12.6
Falling from one's own height	10	9
Injury from a traumatic weapon	2	1.8
Injury under unknown circumstances	22	19.8

In addition to midface injuries, all the patients (n=111) were diagnosed with TBI. Open TBI was diagnosed in 70 (63,1%) patients and closed TBI - in 41 (36,9%). Injuries in the chest area occurred in 37 (33.3%) patients; limb injuries - in 33 (29.7%); abdomen - in 10 (9%); spine - in 9 (8.1%); pelvis - in 6 (5.4%); and neck - in 3 (2.7%) patients. On average, without taking into account the midface injury, each patient was diagnosed with damage to 1.9 anatomical areas. The distribution of injuries by anatomical areas in the examined patients is presented in Table 3.

Table 3. Distribution of injuries by anatomical areas in patients with concomitant midface trauma

Anatomical area	Number of patients, n=111	
	absolute number	%
Head (TBI)	111	100
Neck	3	2.7
Chest	37	33.3
Stomach	10	9
Pelvis	6	5.4
Spine	9	8.1
Limbs	33	29.7

Injuries in the head area were assessed as injuries leading in severity in 91.9% of cases (in 102 patients); chest injuries, as well as limb injuries - in 2.7% (in 3 patients,

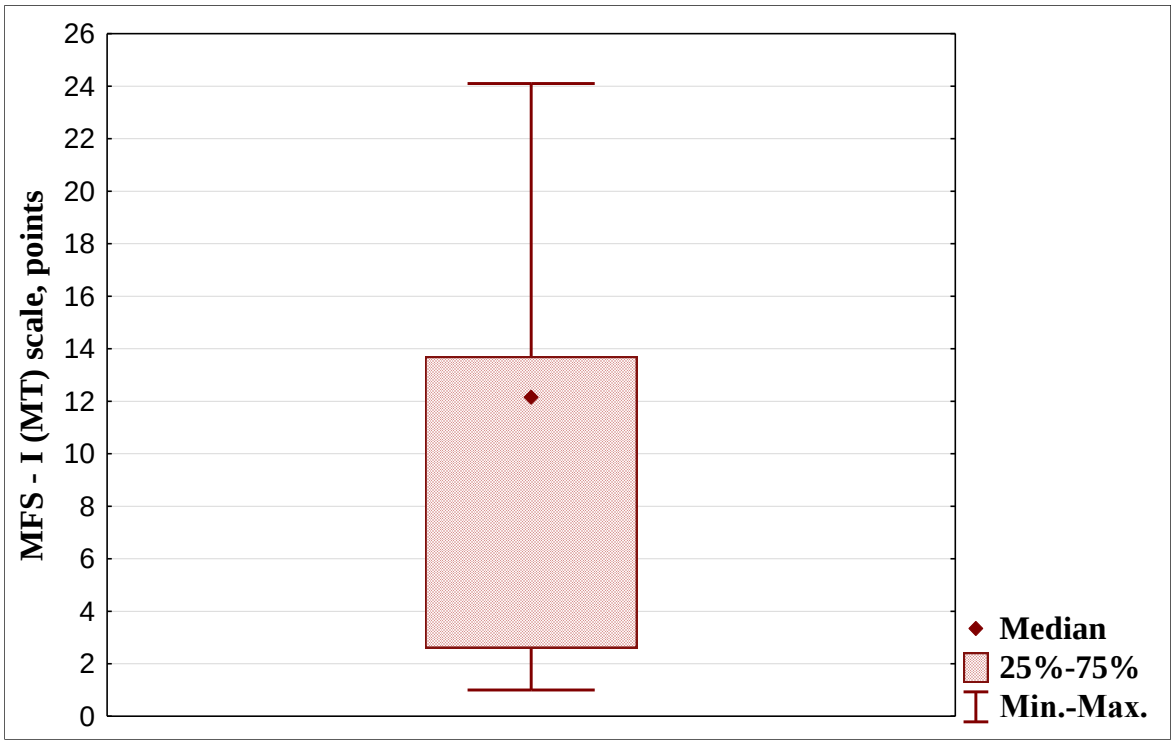
respectively); spine area - in 1.8% (in 2 patients); abdominal area - in 0.9% (the 1 patient).

Among the fractures of the midface bones, the first place is occupied by fractures of the eye socket walls, which were diagnosed in 61 (55%) patients. The second place is occupied by fractures of the upper jaw - in 43 (38.7%) patients. Fractures of the upper jaw of the upper type were observed in 25 (22.5%) patients; of the middle type - in 29 (26.1%); of the lower type - in 18 (16.2%). Fractures of the zygomatic bone occurred in 40 (36%) patients; of nasal bones - in 37 (33.3%) patients. Soft tissue injuries of the midface region were diagnosed in 66 (59.5%) patients. The distribution of midface injuries in the examined patients is presented in Table 4.

Table 4. Distribution of midface injuries in the examined patients

Anatomical location	Number of patients, n=111	
	absolute number	%
Upper jaw	43	38.7
Eye socket	61	55
Zygomatic bone	40	36
Nose bones	37	33.3
Soft tissues	66	59.5

The severity of injuries on the MFS-I 'MT' scale in the examined patients ranged from 1 to 24.1 points (median = 12.2 points); on the ISS scale - from 9 to 50 points (median =29 points). 54 patients had severe injuries (1 to 12 on the MFS-I (MT) scale); 57 patients had extremely severe injuries (≥12 points on the MFS-I (MT) scale). The severity of injuries in the examined patients is shown in Figure 2.



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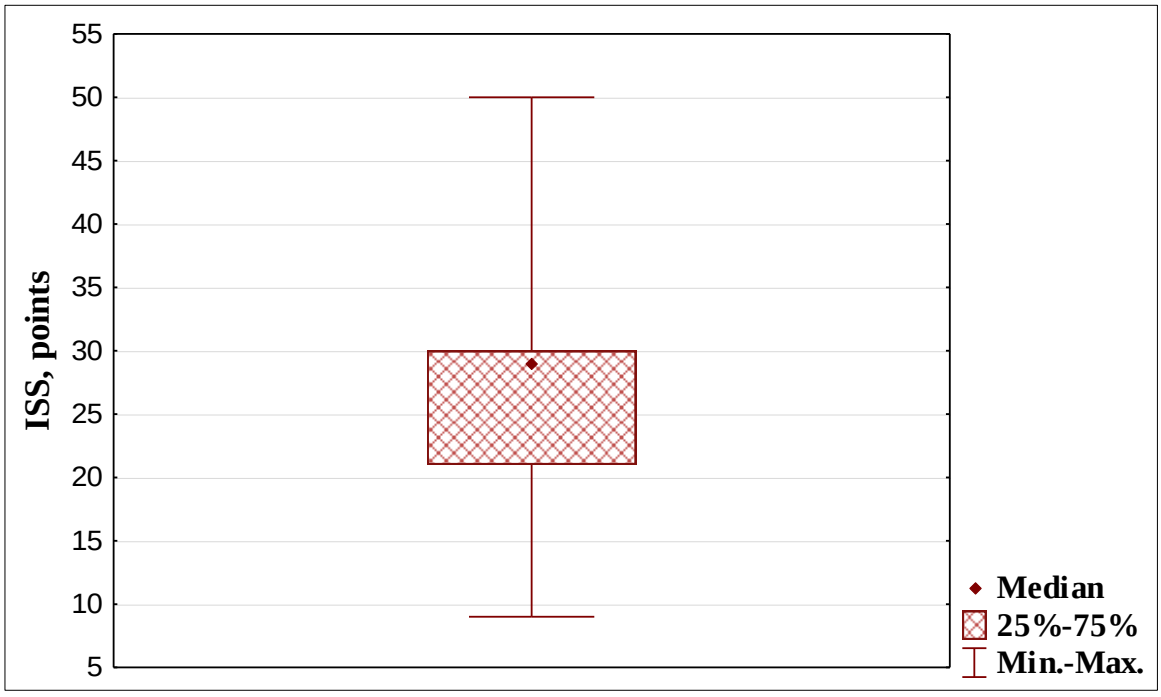


b

Figure 2. Severity of injuries in the examined patients: a) on the MFS-I (MT) scale; b) on the ISS scale.

In the group of 95 patients, traumatic shock upon admission to the clinic was diagnosed in 78.9% (n=75) of cases. Traumatic shock of the second degree was observed in 36 of 75 patients (48%); of the first degree in 30 (40%); and of the third

degree in 9 (12%). Table 5 shows the distribution of patients by severity of shock, indicating the approximate amount of blood loss and the value of the Allgöwer shock index.

Table 5. Distribution of patients by severity of shock

Severity of shock	Number of patients, (n=75)		Approximate blood loss, l	Allgöwer shock index (M±SD)
	absolute number	%		
I degree	30	40	0,5-1	0,9±0,3
II degree	36	48	1-1,5	1,1±0,4
III degree	9	12	More than 1.5	1,3±0,3

To address the research objectives, three subsets were formed from the total dataset (n=111 patients), which will be referred to as the first, second, and third subsets of data, respectively:

1. The first data subset (retrospective data subset). Includes 63 patients. 22 physiological signs reflecting the severity of their physiological status in the course of traumatic disease were studied in the patients of this subset. The patients were divided into 2 groups depending on the immediate outcomes of the concomitant midface injury. The first group – patients with a favourable outcome (n=30 (47,6%)); the second group – patients with an unfavourable outcome (n=33 (52,4%)). In accordance with the expert assessment of the injury severity on the 3rd day after the injury occurred, 2 groups were also formed. The first group, corresponding to a severe injury, included 30 (47.6%) patients; the second group, corresponding to an extremely severe injury, included 33 (52.4%) patients. Despite the equality of the number of patients in the groups formed depending on the immediate outcomes and as a result of the expert assessment, the composition of the groups differs. We used the data of the first subset to address the first and second tasks of this study (searching for syndrome complexes and signs characterising the severity of the physiological status of patients with concomitant midface trauma in the course of traumatic disease; developing of the model for assessing the trauma severity on the third day of hospital stay and the model for

predicting visceral infectious complications; developing a methodology for predicting the immediate outcomes of concomitant midface trauma).

2. The second data subset. It includes 48 patients with severe concomitant midface trauma (from 1 to 12 points on the MFS - I (MT) scale). Based on the data of the second subset, two groups were created: the first group (conventionally called the first group of observed patients) – includes 27 (56.25%) patients, whose treatment was carried out using the treatment algorithm developed in this study; the second group (conventionally called the first retrospective group) – includes 21 (43.75%) patients, whose treatment was carried out by the traditional clinical method.

3. The third data subset. It includes 57 patients with extremely severe concomitant midface trauma (≥12 points on the MFS - I (MT) scale). The patients of the third data set were divided into two groups: the first group (conventionally called the second group of observed patients) – includes 21 (36.8%) patients, whose treatment was carried out, as in the patients of the first group of observed patients, using the treatment algorithm developed in this study; the second group (conventionally called the second retrospective group) – includes 36 (63.2%) patients treated with the traditional clinical method. We used data from the second and third subsets to address the third task of the study (evaluation of the effectiveness of the MST tactic in patients with severe and extremely severe concomitant midface trauma). Table 6 presents the general characteristics of the research material. The formation of two test subsets from the dataset was carried out to address the third research objective, aiming to maximize the preservation of homogeneity within the comparison groups based on the severity of the trauma. Figure 3 shows how the number of patients of the three data subsets has evolved over time.

Table 6. General characteristics of the research material

Data subset	Type of material/ quantity	Comparison groups/ number	Objectives
1	Case histories of patients with combined midface trauma/ n=63.	Depending on the immediate outcomes of combined midface trauma: - First group: patients with a favorable outcome / n=30 (47.6%). - Second group: patients with an unfavorable outcome / n=33 (52.4%). According to the expert assessment of the trauma severity on the 3rd day of hospital stay: - First group (severe trauma) / n = 30 (47.6%). - Second group (extremely severe trauma) / n = 33 (52.4%).	Search for signs characterizing the severity of the physiological status of patients in the course of traumatic disease; Development of a model for assessing the severity of injuries on the 3rd day of hospital stay; Developing of a methodology for predicting immediate outcomes.
2	Clinical material and case histories of patients with severe combined midface trauma/ n=48.	The first group of own observations / n=27 (56.25%). - The first retrospective group / n=21 (43.75%).	Comparative analysis of treatment results of patients with severe combined midface trauma.
3	Clinical material and case histories of patients with extremely severe combined midface trauma/ n=57.	- The second group of own observations / n=21 (36.8%). - The second retrospective group / n=36 (63.2%).	Comparative analysis of treatment results of patients with extremely severe combined midface trauma.

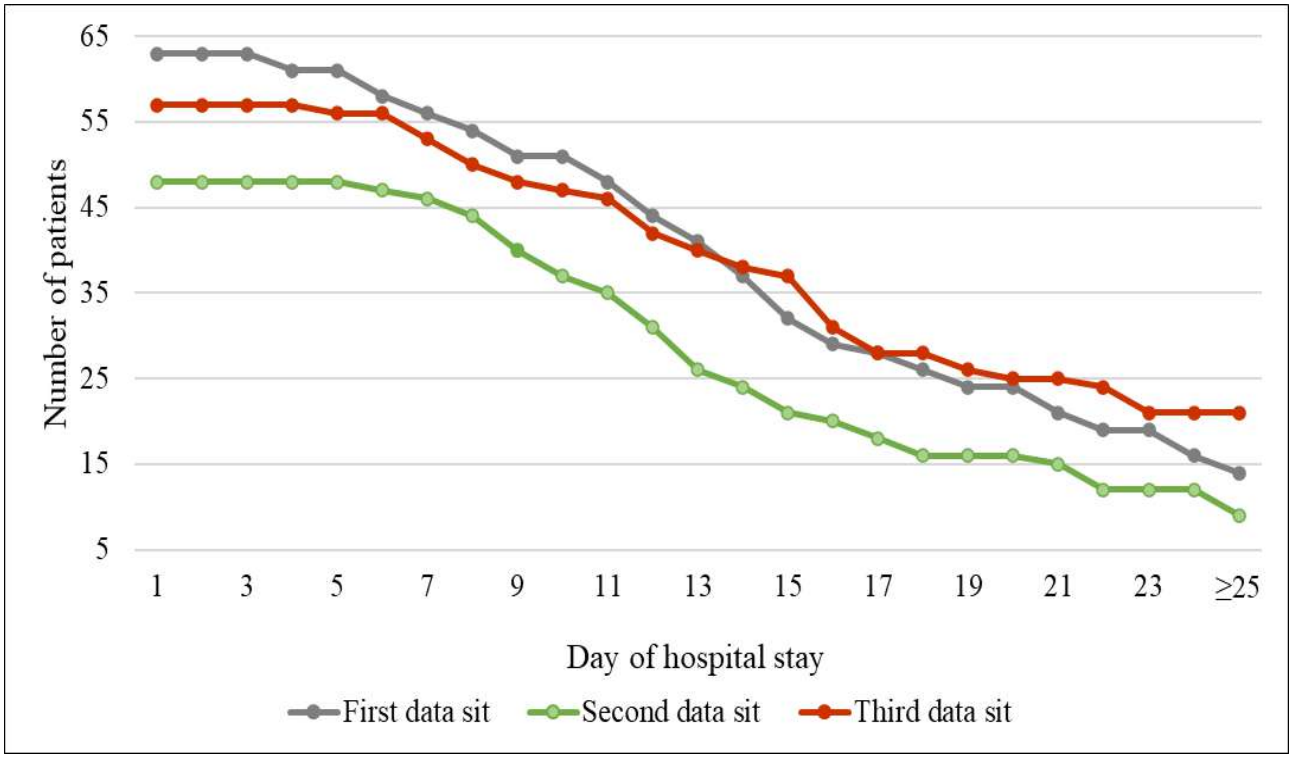


Figure 3. Change in the number of patients of the three data sets over time.

2.1.2. Description of the physiological Signs studied

The severity of the physiological status of patients can be measured by the degree of deviation of physiological signs from the physiological norm. The greater the magnitude of these deviations, the more severe the physiological status.

Observation time is an important component of any medical research. B.B. Bondarenko et al. described four variants of the time of change in the sign values from the observer's point of view: 1. time of examination; 2. calendar time; 3. time of the sign; 4. time of the course of the disease (most often used) [4]. In our study, the signs were measured in two time variants. The first variant is the time of the course of the traumatic illness (1st, 3rd, 7th, and 14th days from the moment of injury), and the second variant is the time of waiting for the outcome (on the last day before the fatal outcome (only in the group of patients with an unfavourable outcome). The time point in the second variant of the observation time will be designated as day -1.

Below we provide a list of the signs we are investigating (22 signs) with the indication of the number and code of each one. A brief description of the physiological significance of the signs is also given.

BT / (1) The body temperature of the patients (36.8 ° C) - hyperthermia may indicate general intoxication as a result of the development of local, visceral, or generalised infectious complications. Spontaneous hypothermia often occurs on the first day after injury, especially if the injury is accompanied by massive blood loss.

HR / (2) Heart rate (from 60 to 100 beats per minute) characterises cardiac activity and the state of haemodynamics. Tachycardia is a sign of general intoxication with the development of infectious complications in patients.

SBP/ (3) Systolic blood pressure (120 mmHg) reflects the state of haemodynamics and the state of the cardiovascular system. A decrease in systolic blood pressure to 80 mmHg and below indicates the instability of haemodynamics and is an indication for inotropic support. If, at the time of measuring the sign, inotropic support was provided to the patient, then systolic blood pressure was automatically assessed at 80 mmHg.

Hb / (4) Haemoglobin (120-140 g / l for women; 130-160 g / l for men) - acute posthemorrhagic anemia occurs as a direct result of mechanical damage to tissues and organs, accompanied by massive blood loss. The process of erythropoiesis and the level of haemoglobin can also be affected by the development of infectious and purulent-septic complications in patients. Haemoglobin is also an indirect sign of oxygenation of tissues and organs.

WBC / (5) Leukocytes (4-8.8×10^9 /l) - the level of leukocytes reflects the state of immune-reactive processes and resistance of the body during the development of infectious complications. Interpretation of the values of this sign should be carried out taking into account other signs of infectious complications, since patients with severe trauma often develop redistributive leukocytosis, especially in the first and second periods of traumatic illness.

Lym/ (6) Lymphocytes (1,2-3,0×10^9/l) are the main cells of the immune system responsible for humoral and cellular immunity. Reflect the state of resistance of the

body and the nature of the immune response in the development of infectious complications.

Mono/ (7) Monocytes (0.29-0.6×10^9/l) are cells of the immune system involved in the process of phagocytosis in infectious complications.

NLR/ (8) Neutrophil-Lymphocyte Ratio (0.78-3.5) is an indicator of the morphological composition of leukocytes, reflecting the severity of the 'stress load' of the immune system [221]. It is calculated by dividing the absolute number of neutrophils by the number of lymphocytes.

$$NLR = \frac{\text{number of neutrophils}}{\text{number of lymphocyte}}, \quad (1)$$

The greater the 'stress load' of the immune system, the greater the number of neutrophils, the smaller the number of lymphocytes and the higher the NLR index [222].

LII/ (9) Leukocyte Intoxication Index (LII) according to Ya.Ya. Kalf-Kalif (0.5-1.0) - reflects the severity of the infectious process and endogenous intoxication. An increase in LII to 4.0 or more is considered a sign of significant endogenous intoxication [39]. LII is calculated by the following formula:

$$LII = \frac{(S+2R+3Y+4MYC)(PC+1)}{(Mono+Lym)(Eo+1)}, \quad (2)$$

where S – segmented neutrophils;

R – rod-shaped neutrophils;

Y – young;

MYC – myelocytes;

PC – plasma cells;

Mono – monocytes;

Lym – lymphocytes;

Eo – eosinophils.

ALT / (10) Alanine aminotransferase (≤34 U/l for women; ≤45 U/l for men) is an indicator of the severity of damage to liver cells in violation of its function and the development of organ failure.

Bil./ (11) Total blood bilirubin (2.5- 20.5 mmol/L) - reflects the functional state of the liver. Hyperbilirubinemia in patients with severe trauma may be the result of increased haemolysis in infectious and purulent-septic complications or impaired liver function and organ failure.

BG / (12) Blood glucose (3.89- 6 mmol /L) - stress hyperglycemia often develops with a complicated course and an unfavourable outcome of critical physiological statuss. The mechanism of its development is associated with hypersecretion of glucocorticoids and catecholamines, which lead to activation of lipolysis, gluconeogenesis, inhibition of aerobic glycolysis, suppression of insulin secretion, and the development of insulin resistance [37].

Na+/ (13) Concentration of sodium ions in the blood (136-145 mmol/L) - sodium ions are the main cation of extracellular fluid, which plays an important role in regulating the water balance, maintaining blood pressure, conducting nerve impulses, and muscle contraction. Hypernatremia can occur against the background of hypovolemia as a result of blood loss and a decrease in the volume of circulating blood. Hypernatremia can also be iatrogenic as a result of excessive administration of sodium ions, a tactic that is sometimes used to combat cerebral oedema [145]. Dysnatremia is an indirect sign of impaired function of the excretory system and the development of renal failure.

K+/ (14) Concentration of potassium ions in the blood (3.5- 5.1 mmol/L) - potassium ions are the main cation of the intracellular fluid whose main function is the regulation of neuromuscular excitability. Violation of the concentration of potassium ions in the body has a negative effect on the work of the respiratory muscles and cardiac activity. The level of potassium in the blood is regulated mainly by renal excretion under the action of the hormone aldosterone, therefore, a violation of potassium concentration may indicate kidney dysfunction and the development of renal failure.

Cl-/ (15) The concentration of chlorine ions in the blood (98- 107 mmol/L) is the main anion of extracellular fluid, participates in the regulation of osmotic pressure, muscle activity, and acid-base balance. An indirect sign of a violation of the function of the excretory system and the development of metabolic acidosis.

BU / (16) Urea in the blood (3- 9.2 mmol/L) is the final product of protein breakdown and an indicator of the functional state of the excretory system.

INR/ (17) International normalised ratio (0.8- 1.2) is a standardised indicator of blood clotting. Reflects the severity of post-traumatic coagulopathy [6, 18].

pH/ (18): hydrogen index (7,350-7,450) is an indicator of blood acidity and acid-base balance. Blood buffer systems, lungs, and kidneys are involved in the regulation of pH levels. Deviation of pH from the physiological norm indicates the development of acidosis or alkalosis. Both physiological statuss may have respiratory (with reduced respiratory efficiency) or metabolic (with impaired renal function) mechanisms of development. To differentiate the aetiology of acidosis or alkalosis, the pH level must be evaluated together with the partial pressure of carbon dioxide (pCO2) and the level of blood bicarbonate (HCO3-).

pCO_2/ (19): partial pressure of carbon dioxide in arterial blood (32-48 mmHg) is an indicator characterising the adequacy of pulmonary ventilation and the respiratory link of the acid-base state. The pCO_2 level is used to determine the type of respiratory failure and to establish the nature and aetiology of acid-base disorders.

pO2/ (20): partial pressure of oxygen in arterial blood (83 - 108 mmHg) - reflects the adequacy of the process of oxygenation of blood in the lungs, and the amount of oxygen available to the body, not related to haemoglobin. pO2 is used in the diagnosis of hypoxemia and respiratory failure.

SO2/ (21): Haemoglobin oxygen saturation in arterial blood (95-99%) is an important sign of blood oxygenation. Oxygen associated with haemoglobin accounts for up to 98% of the total amount of oxygen in the blood. pO_2 is a glycemic factor that determines the level of SO2. The level of haemoglobin oxygen saturation is used in the diagnosis of respiratory failure.

HCO3-/ (22): Blood bicarbonate level (21.2-27 mmol/L for women; 22.2-28.3 mmol/L for men) is a metabolic component of the acid-base state and the main component of the blood buffer system. The HCO3 level is used in the diagnosis of the nature and aetiology of acid-base balance disorders. Violation of HCO3 concentration is also an indirect sign of renal failure.

2.2 Research methods

2.2.1. Methodology of Data Collection

When collecting clinical material, generating a preliminary dataset, and mathematical processing of research data, the author was guided by the general principles of the biometric analysis of medical data described by Professor D.Yu. Madai and Candidate of Physics and Mathematics A.G. Barth et al. in the textbook 'Biometric Analysis of the Effectiveness of Treatment' [12].

The methodology involves measuring a feature or features under study at several predetermined and fixed time points for all the patients involved in the study. These time points in our study corresponded to the 1st, 3rd, 7th, 14th days after the injury. These time points were chosen taking into account the theory of traumatic illness generally accepted in traumatology and correspond to its periods. This technique allows one to observe the dynamics of changes in the studied feature in different periods of traumatic illness, which in turn allows one to study the features and nature of its course. The values of the studied features were also collected for the last day of life of patients with a fatal outcome of combined trauma.

The generated dataset includes 77 qualitative variables and 114 quantitative variables and consists of several data units:

1. The first unit includes general data about the patients, such as data identifying the patients, the age of the patients, the duration of hospital stay, concomitant diseases, and other general data.

2. The second unit contains data on the injury itself, the mechanism of its occurrence, diagnosis, treatment, complications, outcome, and other qualitative data.

3. The third unit is the most massive and includes indicators of clinical and laboratory indicators measured at the above-mentioned five time points.

4. The fourth unit contains data on the severity of injuries and the physiological status of the examined patients.

2.2.2. Radiation methods of examination of patients

The method of multi spiral computed tomography (MSCT) was used as the main method of radiation diagnosis of craniofacial injuries. Computed tomography was performed on all the patients upon admission to hospital. Repeated computed tomography was also performed, if necessary, after the initial stabilisation of the physiological status of the patients and after the final fixation of midface bone fractures.

During the computed tomography, the clinic's standard equipment was used - the Aquilion 16 CT scanner from Toshiba (Japan) with a 16-detector multi-slice scanning system (Registration certificate No. FSZ 2007/00892) and the Somatom Definition AS spiral CT scanner from Siemens (Germany) with a 128-detector multi-slice scanning system (Registration certificate No. FSZ 2008/02797).

2.2.3. Study of Clinical and Laboratory Signs Reflecting the Severity of the Physiological status of the Patients

Measurement of clinical and laboratory physiological signs was carried out using standard equipment of the clinic:

1. The PICCO Plus Haemodynamic Monitor by PULSE (Germany) (Registration certificate No. FS 2005/511): was used to measure heart rate (HR) and blood pressure (BP).

2. Haematological analyser KX -21N by Sysmex (Japan) (Registration certificate No. FSZ 2011/11182) was used to measure the number of leukocytes, lymphocytes, monocytes, and haemoglobin levels in venous blood.

3. Biochemical analysers iLab Taurus by Instrumentation Laboratory (Italy) (Registration certificate No. FSZ 2012/12577), Cobas Integra 400 plus by Roche Diagnostics (Switzerland) (Registration certificate No. FSZ 2012/11531), and Architect c8000 Processing Module by Abbott Laboratories Diagnostics Division and Toshiba Medical Systems Corporation (USA, Japan) (Registration certificate No. REN 2014/2010) were used to measure the level of alanine aminotransferase (ALT), total bilirubin, glucose, urea, as well as concentrations of potassium (K+), sodium (Na+), and chlorine (Cl-) ions in blood.

4. Coagulation analyser CS 5100 e by Sysmex (Japan) (Registration certificate No. RZN 2013/762) was used to determine the international normalised ratio (INR).

5. The analyser of acid-base and gas composition of blood of the ABL800 Flex series by Radiometer Medical ApS (Denmark) (Registration certificate No. RZN 2015/2415) was used to measure the partial pressure of carbon dioxide (pCO2), partial pressure of oxygen (pO2), hydrogen index (acidity- pH), the level of oxygen saturation of haemoglobin in arterial blood (sO2), and blood bicarbonate (cHCO3) concentrations.

2.2.4. Methods for Assessing the Severity of Concomitant Midface Trauma

Assessment of the severity of injuries in the patients studied was carried out using two widely used methods: the MFS - I (MT) method of injury severity assessment and the ISS injury severity scale.

2.2.4.1. Injury Severity Score MFS-I (MT)

To assess the severity of injuries on this scale, the points for each injury diagnosed in a patient are summed up. The scale contains 84 names for the most common injuries in clinical practice. Table 7 shows the names of injuries in the head area and the number of points assigned to them, according to this scale.

Table 7. Assessment of the severity of injuries on the MFS - I (MT) Head scale [cited by: 20, p. 722]

Item no.	Type of injury	MFS - I
1	Wounds of the soft tissues of the head	0.05
2	Closed fractures of the bones of the nose	0.2
3	Concussion of the brain	0.2
4	Fractures of the jaws	0.3
5	Mild brain contusion	0.3
6	Moderate brain contusion with fractures of the vault of the skull	0.5
7	Moderate brain contusion with closed fractures of the vault and base of the skull	0.6
8	Moderate brain contusion with open fractures of the vault and base of the skull	2
9	Compression of the brain accompanied by mild contusions	7
10	Severe brain contusion with damage to the upper brainstem	12
11	Compression of the brain accompanied by severe contusions	18
12	Severe brain contusion with damage to the lower brainstem	19

The calculated sum of points is subsequently subject to interpretation in the traditional qualitative gradations of severity. Light injuries have quantitative values in the range of 0.05 - 0.49 points; moderate injuries in the range of 0.5 - 0.99 points; and severe injuries in the range of 1.0 - 12.0 points. Injuries with a severity of > 12.0 points are extremely severe (Table 8).

Table 8. Gradation of severity of injuries in patients [cited by: 20, p. 729]

Traditional injury gradation	Quantitative assessment of injuries (score)
Mild	0,05 - 0,49
Moderate	0,5 - 0,99
Severe	1,0 - 12,0
Extremely severe	> 12,0

2.2.4.2. Injury Severity Score ISS

To calculate the severity of injuries on the ISS scale, the scoring method proposed in the AIS scale is used. According to the AIS scale, each injury, depending on its severity, is assigned a certain number of points. Mild injury is estimated at 1 point; moderate injury at 2 points; severe injury without a threat to life at 3 points; severe injury with a threat to life at 4 points; critical injury at 5 points; fatal injury (injury incompatible with life) at 6 points (Table 9) [203].

Table 9. Qualitative and quantitative gradation of injury severity on the AIS scale

Gradation of injury severity	Value in points
Mild injury	1
Moderate injury	2
Severe injury without threat to life	3
Severe life-threatening injury	4
Critical injury	5
Fatal injury - incompatible with life	6

To calculate the severity of injuries on the ISS scale, add up the squares of points on the AIS scale of the three most severe injuries in three different anatomical areas. According to the AIS and ISS scales, injuries are assessed in six anatomical areas: head and neck, face, chest, limbs and pelvic organs, abdomen, and external integuments [203].

Thus, the sum of points on the ISS scale varies from 1 to 75. In the presence of one fatal injury incompatible with life, 75 points are automatically assigned to it, despite the severity of other injuries [203].

There are no clear quantitative boundaries in the ISS scale, which are necessary for interpreting the sum of points obtained in assessing severity into qualitative gradations of severity. However, in the field of traumatology, it is customary to attribute injuries with a score of 17 >to severe and polytrauma [25].

2.2.5. Expert assessment of the severity of combined midface trauma

To solve the problem of developing a model for assessing the severity of trauma for patients in the intensive care units on the 3rd day of hospital stay, the medical records of 63 patients with combined midface trauma were subjected to expert assessment of the severity of injuries. During the expert assessment, the following features were taken into account: the age of the patient, the presence or absence of concomitant diseases in the anamnesis, the expected amount of blood loss, the state of hemodynamics, the severity of anatomical injuries and the development of life-threatening complications in the first period of traumatic disease.

2.2.6. Statistical Processing of Research Data

Statistical processing of the research data was carried out using the STATISTICA 10.0 applied software package together with Associate Professor of the Department of General Mathematics and Computer Science of St Petersburg University V.A. Bart. When describing the results of the study, the author was guided by the recommendations and requirements of leading modern specialists in presenting the results of medical research and, in particular, the recommendations of Professor T.A. Lang [3, 42].

At the stage of exploratory analysis of the study data, it was found that the vast majority of the studied quantitative features had a normal or logarithmically normal

distribution. Measures of the central trend and the range of features with a normal distribution will be presented in the format of the mean (M) and standard deviation (SD); features with a logarithmic normal distribution - in the form of median (Mdn), minimum (Min), and maximum values (Max). In order to unify the format for presenting descriptive statistics of features, measures of central trend and scope in the section 'exploration analysis' will be presented in the form of median (Mdn), minimum (Min), and maximum (Max) values. The hypothesis of the equality of means across groups was tested using the Mann-Whitney test or the Student's t-test. The hypothesis about the absence of differences in the frequencies of qualitative variables was tested using Pearson's $\chi 2$ test or Fisher's exact test.

Factor analysis (the principal component method) was used as the main method of identifying syndrome complexes (factors) characterising the severity of the physiological status of patients in the last day before the onset of death, as well as to determine the optimal time point for predicting the nearest outcomes. The use of factor analysis made it possible to reduce the total number of signs without significant loss of information.

Correlation analysis and correlation pleiades were used to assess the strength and significance of the interrelationships of the features forming the selected factors.

Discriminant analysis was applied in the creation of a mathematical model for predicting the immediate outcomes of concomitant midface trauma and the likelihood of developing visceral infectious complications, as well as model for assessing the severity of trauma and classifying patients on the 3rd day of hospital stay.

CHAPTER 3.
CLINICAL AND BIOMETRIC APPROACH TO ASSESSING THE SEVERITY OF THE PHYSIOLOGICAL STATUS OF PATIENTS WITH CONCOMITANT MIDFACE TRAUMA

3.1. Biostatistical analysis of the significance of individual physiological signs and syndrome complexes for the objective assessment of the physiological status of patients with combined midface trauma in the dynamics of the course of traumatic disease

Decompensation of the physiological status of the patients is a complex and heterogeneous process, which is based on severe violations of the function of vital organs and body systems. The pattern of these violations may differ among different patients, depending on which systems and organs are more affected. The main element in the decompensation of the physiological status can be severe violations of the functions of one vital system or one or more organs. It is this, as well as the difference between the initial (before the injury) state and the physiological resources of the body in different patients, that causes the heterogeneity of this process.

Tables 10, 11, 12, 13, 14 present descriptive statistics of the studied parameters for patients with favorable and unfavorable outcomes. The p-level of significance of differences in the mean values of the studied parameters by groups using the Mann-Whitney test is also given. It should be noted that the number of patients studied at each time point and the number of measurement conducted for each parameter may differ. This is due to organizational, technical and financial reasons, including the policy of managing patients with severe trauma at the clinical site where the study is conducted. For the same reasons, studies of parameters related to blood gas analysis, which is performed only in intensive care units, were conducted much less frequently than others.

Table 10. Descriptive statistics of signs on Day 1

Sign		Favourable		Unfavourable		Mann-Whitney Test, P-level
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
1	BT	30	36,80 [36,00; 37,70]	33	36,70 [35,90; 38,60]	0.979
2	HR	30	101,00 [70,00; 160,00]	33	110,00 [62,00; 151,00]	0.200
3	SBP	30	113,00 [60,00; 160,00]	33	111,00 [70,00; 160,00]	0.841
4	Hb	29	117,00 [54,00; 154,00]	31	104,00 [60,00; 153,00]	0.107
5	WBC	29	16,35 [4,87; 27,27]	31	13,56 [4,88; 24,06]	**0.040**
6	Lym	29	1,44 [0,19; 3,31]	31	0,67 [0,11; 2,75]	**0.001**
7	Mono	29	1,00 [0,09; 2,33]	31	0,74 [0,10; 2,08]	0.141
8	NLR	29	9,17 [0,96; 31,33]	31	17,05 [0,98; 46,94]	**0.012**
9	LII	29	5,60 [1,05; 13,08]	31	7,05 [0,87; 19,98]	**0.030**
10	ALT	27	47,00 [17,00; 167,00]	32	33,00 [8,00; 116,00]	**0.042**
11	B	27	14,20 [1,90; 33,80]	32	12,85 [6,00; 31,20]	0.805
12	BG	29	7,85 [4,61; 14,10]	32	9,59 [5,02; 15,75]	**0.004**
13	Na+	27	139,00 [132,00; 149,00]	32	141,00 [133,00; 155,00]	0.227
14	K+	27	3,80 [2,60; 5,70]	32	3,80 [2,52; 5,10]	0.568
15	Cl-	27	108,50 [99,00; 117,00]	32	106,00 [96,00; 116,00]	0.386
16	BU	27	4,00 [1,30; 11,90]	32	5,50 [2,00; 12,90]	0.147
17	INR	27	1,10 [0,86; 1,44]	32	1,13 [0,86; 1,49]	0.730
18	pH	25	7,38 [7,31; 7,55]	29	7,40 [7,20; 7,56]	0.578
19	pCO_2	25	32,20 [22,30; 49,00]	29	33,35 [24,50; 50,00]	0.214
20	pO_2	25	116,00 [27,00; 192,00]	29	125,00 [70,20; 178,00]	0.707
21	SO_2	25	98,85 [96,90; 100,00]	29	95,20 [35,00; 98,90]	**0.000**
22	HCO_3-	25	21,70 [16,40; 27,10]	29	21,80 [16,00; 26,30]	0.796

Table 11. Descriptive statistics of signs on Day 1

Sign		Favourable		Unfavourable		Mann-Whitney Test, p-level
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
1	BT	30	36,80 [36,00; 37,80]	33	37,20 [36,00; 39,00]	0.064
2	HR	30	79,50 [68,00; 130,00]	33	101,00 [68,00; 126,00]	**0.005**
3	SBP	30	120,00 [90,00; 140,00]	33	120,00 [75,00; 150,00]	0.548
4	Hb	25	94,50 [64,00; 145,00]	31	89,00 [64,00; 140,00]	0.139
5	WBC	25	9,62 [4,01; 15,44]	30	10,59 [3,01; 21,20]	0.217
6	Lym	25	1,05 [0,14; 2,63]	30	0,65 [0,17; 1,70]	**0.000**
7	Mono	25	0,95 [0,13; 1,87]	30	0,62 [0,01; 1,45]	0.075

Continuation of Table 11

8	NLR	25	5,88 [1,99; 19,29]	30	16,48 [3,94; 29,10]	**0.000**
9	LII	25	3,89 [1,86; 9,09]	30	8,89 [3,06; 16,80]	**0.000**
10	ALT	23	40,00 [14,00; 103,00]	27	32,00 [6,00; 100,00]	0.275
11	B	23	16,10 [4,30; 32,80]	27	10,15 [1,50; 31,90]	0.202
12	BG	27	5,89 [4,27; 7,27]	29	7,35 [4,20; 12,05]	**0.000**
13	Na+	26	136,00 [132,00; 144,00]	28	143,00 [134,00; 159,00]	**0.000**
14	K+	26	4,20 [3,30; 5,20]	28	3,90 [2,90; 4,80]	**0.001**
15	Cl-	26	108,00 [99,00; 116,00]	28	110,00 [98,00; 125,00]	**0.026**
16	BU	23	5,05 [1,90; 8,70]	27	6,60 [2,40; 19,60]	**0.005**
17	INR	23	1,08 [0,92; 1,25]	27	1,19 [0,99; 1,50]	**0.010**
18	pH	20	7,48 [7,33; 7,54]	26	7,39 [7,26; 7,53]	**0.017**
19	pCO_2	20	31,70 [23,40; 38,00]	26	36,70 [24,50; 50,80]	**0.024**
20	pO_2	20	132,00 [53,00; 198,00]	26	162,00 [118,00; 206,00]	**0.008**
21	SO_2	20	98,70 [96,00; 100,00]	26	98,70 [95,00; 99,80]	0.425
22	HCO_3-	20	23,55 [17,50; 29,00]	26	23,60 [16,30; 28,00]	0.690

Table 12. Descriptive statistics of signs on Day 7

Sign		Favourable		Unfavourable		Mann-Whitney Test, p-level
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
1	BT	30	36,70 [36,20; 38,10]	28	37,30 [35,10; 39,90]	**0.037**
2	HR	30	74,50 [68,00; 143,00]	28	102,00 [68,00; 151,00]	**0.000**
3	SBP	30	120,00 [100,00; 136,00]	28	111,00 [77,00; 160,00]	0.077
4	Hb	22	97,50 [77,00; 115,00]	28	91,00 [66,00; 117,00]	0.051
5	WBC	21	9,41 [6,99; 21,80]	24	12,18 [3,84; 19,58]	0.707
6	Lym	21	1,08 [0,53; 2,67]	24	0,90 [0,18; 1,74]	0.088
7	Mono	21	1,32 [0,39; 3,06]	24	0,92 [0,07; 2,52]	**0.025**
8	NLR	21	7,67 [2,49; 14,58]	24	11,20 [3,49; 27,52]	**0.006**
9	LII	21	3,57 [1,77; 7,11]	24	6,48 [2,31; 19,50]	**0.000**
10	ALT	19	50,00 [13,00; 157,00]	21	46,00 [5,00; 196,00]	0.762
11	B	19	23,00 [6,30; 98,40]	21	11,30 [1,70; 29,90]	**0.049**
12	BG	23	5,39 [3,86; 7,66]	24	6,65 [4,10; 10,00]	**0.019**
13	Na+	20	137,00 [131,00; 143,00]	23	143,45 [129,00; 152,00]	**0.000**
14	K+	20	4,40 [3,60; 5,20]	23	3,90 [2,80; 5,00]	**0.003**
15	Cl-	20	106,00 [97,00; 115,00]	23	111,00 [94,00; 123,00]	**0.002**
16	BU	19	4,40 [2,10; 8,70]	21	9,10 [3,20; 19,20]	**0.003**
17	INR	19	1,23 [1,02; 1,45]	21	1,28 [0,96; 1,59]	0.400
18	pH	14	7,46 [7,36; 7,52]	20	7,40 [7,23; 7,52]	0.079
19	pCO_2	14	32,00 [25,00; 43,50]	20	33,40 [28,20; 38,90]	0.540

Continuation of Table 12

20	pO_2	14	82,50 [42,50; 150,00]	20	148,00 [48,00; 212,00]	**0.006**
21	SO_2	14	98,50 [95,00; 99,60]	20	98,30 [95,00; 100,00]	0.767
22	HCO_3-	14	23,45 [18,30; 28,40]	20	21,60 [14,70; 28,50]	0.123

Table 13. Descriptive statistics of signs on Day 14

Sign		Favourable		Unfavourable		Mann-Whitney Test, p-level
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
1	BT	24	36,60 [36,20; 37,50]	17	37,40 [36,00; 39,20]	**0.000**
2	HR	24	77,00 [68,00; 95,00]	17	98,00 [57,00; 144,00]	**0.000**
3	SBP	24	120,00 [112,00; 135,00]	17	100,00 [60,00; 138,00]	**0.000**
4	Hb	13	96,00 [80,00; 124,00]	14	86,00 [81,00; 112,00]	0.121
5	WBC	13	12,24 [5,77; 21,04]	14	12,84 [7,51; 22,61]	0.925
6	Lym	13	1,18 [0,65; 2,07]	14	0,83 [0,28; 1,76]	0.086
7	Mono	13	0,93 [0,43; 2,62]	14	0,63 [0,38; 1,19]	**0.024**
8	NLR	13	7,96 [2,75; 16,29]	14	12,96 [4,84; 31,32]	0.060
9	LII	13	5,57 [2,17; 12,27]	14	9,68 [3,41; 13,27]	**0.038**
10	ALT	11	47,50 [12,00; 95,00]	10	65,30 [8,00; 177,00]	0.350
11	B	11	14,45 [5,20; 47,50]	10	8,80 [2,70; 25,20]	0.396
12	BG	11	5,97 [4,21; 7,07]	10	7,20 [4,80; 14,09]	**0.018**
13	Na+	11	138,00 [134,00; 139,00]	10	142,00 [132,00; 163,00]	0.056
14	K+	11	4,90 [3,80; 6,20]	10	4,10 [3,00; 5,20]	**0.025**
15	Cl-	11	105,00 [94,00; 114,00]	10	115,00 [94,00; 127,00]	0.152
16	BU	11	5,50 [2,00; 13,20]	10	7,25 [3,30; 21,20]	0.105
17	INR	10	1,32 [1,09; 1,44]	10	1,51 [1,18; 1,81]	**0.003**
18	pH	4	7,45 [7,43; 7,50]	11	7,39 [7,24; 7,44]	**0.009**
19	pCO_2	4	33,10 [28,80; 37,20]	11	36,25 [22,30; 51,00]	0.525
20	pO_2	4	75,40 [49,20; 135,00]	11	132,00 [43,00; 148,00]	0.437
21	SO_2	4	97,60 [85,50; 99,00]	11	94,45 [80,00; 98,70]	0.358
22	HCO_3-	4	24,50 [22,50; 25,80]	11	23,25 [14,00; 26,60]	0.396

Table 14. Descriptive statistics of signs for Day -1

Sign		Unfavourable			
No.	Code	n	Median [Min.; Max.]	Lower quartile	Upper quartile
1	BT	31	37,30 [36,10; 40,60]	36.80	38.70
2	HR	33	101,50 [56,00; 155,00]	87.00	119.00
3	SBP	33	82,50 [50,00; 117,00]	70.00	92.50

Continuation of Table 14

4	Hb	29	84,50 [61,00; 117,00]	79.50	95.00
5	WBC	29	11,91 [2,43; 25,20]	8.28	16.35
6	Lym	29	0,81 [0,21; 1,98]	0.50	1.22
7	Mono	29	0,69 [0,03; 1,99]	0.33	1.34
8	NLR	29	12,00 [3,52; 39,31]	8.49	22.80
9	LII	29	7,83 [3,30; 26,24]	5.18	13.70
10	ALT	26	40,50 [9,00; 100,00]	22.50	59.00
11	B	26	10,85 [2,00; 29,10]	7.80	18.35
12	BG	25	7,79 [3,85; 17,57]	5.60	11.20
13	Na+	26	147,00 [131,00; 168,00]	141.50	153.00
14	K+	26	4,00 [2,70; 5,90]	3.35	4.60
15	Cl-	26	114,00 [96,00; 132,00]	107.00	119.00
16	BU	26	12,65 [2,60; 40,30]	6.60	20.45
17	INR	27	1,50 [1,07; 2,18]	1.31	1.74
18	pH	23	7,37 [7,10; 7,52]	7.27	7.44
19	pCO_2	23	34,50 [17,00; 57,00]	29.20	48.70
20	pO_2	23	87,50 [40,20; 299,00]	59.00	182.00
21	SO_2	23	95,20 [80,80; 99,20]	88.00	98.50
22	HCO_3-	23	20,20 [11,10; 27,60]	18.30	23.20

To analyse the patterns of changes in signs reflecting the functional state of the organism, as well as the correlation relationships of these signs, we used indicators of signs collected at the fifth time point (on the last day before the unfavourable outcome).

The total number of patients in the first data subset with an unfavourable outcome was 33. The number of patients included in the study at the fifth time point (-1 day), in whom all signs (22) were measured, was 23.

In order to avoid significant data loss while reducing the number of signs and to maintain the maximum level of informativeness, factor analysis (the method of principal components (PCA)) was used, which is based on the correlation of signs. The nature of the distribution of the values of the sign 21/SO2 is more like categorical and binary signs, despite the attempt to increase the symmetry of its values using the logarithm procedure. For this reason, the sign was excluded from this stage of biometric analysis.

To address the issue of the number of factors that need to be identified as the main ones, we were guided by the criterion of interpretability and invariance, which

assumes the possibility of identifying factors as long as they can be interpreted. At the same time, we took into account the contribution of each factor (eigenvalues) and its share of the total accumulated share of all factors.

The evaluation of the interpretability of factors and their contributions allowed us to identify three factors. The number of signs in the selected factors was reduced based on their factor loads. Signs with a factor load of <0.6 or >-0.6 are excluded from the factors. At that, the total number of signs decreased from 22 to 11. The results of the confirmatory factor analysis are presented in Table 15.

Table 15. Results of confirmatory factor analysis of signs at the fifth time point (Day -1)

Sign		Factors		
No.	Code	1	2	3
4	Hb	-0.04	-0.83	-0.11
6	Lym	-0.92	0.06	0.13
7	Mono	-0.86	0.10	0.07
8	NLR	0.84	0.01	-0.34
9	LII	0.94	-0.02	-0.13
13	Na+	0.30	0.14	0.81
15	Cl-	0.14	0.16	0.87
16	BU	0.26	0.01	0.84
18	pH	0.08	0.91	-0.14
19	pCO2	-0.07	-0.85	0.08
22	HCO3-	-0.09	0.88	-0.20
Factor contribution		3.38	3.07	2.36
The share of the factor's contribution, %		31	28	21
Accumulated share, %		31	59	80

Table 16 shows the correlations of the signs on the last day before the unfavourable outcome and the structure of the correlation pleiades for each of the three factors.

Table 16. Correlations of the signs of the three identified factors

Sign	Lym	Mono	NLR	LII	Na+	Cl-	BU	Hb	pH	pCO2	HCO3-
Lym	1.00	0.72	-0.73	-0.80	-0.11	-0.04	-0.22	0.03	-0.07	0.00	0.11
Mono	0.72	1.00	-0.52	-0.75	-0.17	-0.14	-0.14	-0.05	0.03	0.06	0.13
NLR	-0.73	-0.52	1.00	0.82	-0.07	-0.18	0.05	0.00	0.12	-0.02	-0.03
LII	-0.80	-0.75	0.82	1.00	0.09	0.01	0.10	0.06	0.06	-0.07	-0.05
Na+	-0.11	-0.17	-0.07	0.09	1.00	0.64	0.50	-0.09	0.00	0.02	0.04
Cl-	-0.04	-0.14	-0.18	0.01	0.64	1.00	0.64	-0.18	0.02	-0.18	-0.06
BU	-0.22	-0.14	0.05	0.10	0.50	0.64	1.00	-0.14	-0.02	0.04	-0.25
Hb	0.03	-0.05	0.00	0.06	-0.09	-0.18	-0.14	1.00	-0.71	0.51	-0.64
pH	-0.07	0.03	0.12	0.06	0.00	0.02	-0.02	-0.71	1.00	-0.75	0.75
pCO2	0.00	0.06	-0.02	-0.07	0.02	-0.18	0.04	0.51	-0.75	1.00	-0.71
HCO3-	0.11	0.13	-0.03	-0.05	0.04	-0.06	-0.25	-0.64	0.75	-0.71	1.00

Figure 4 shows a cross-section diagram of the correlation cylinder (correlation pleiades of P.V. Terentyev) of the signs for the last day before the onset of an unfavourable outcome. In general, the diagram illustrates the results of the factor analysis well.

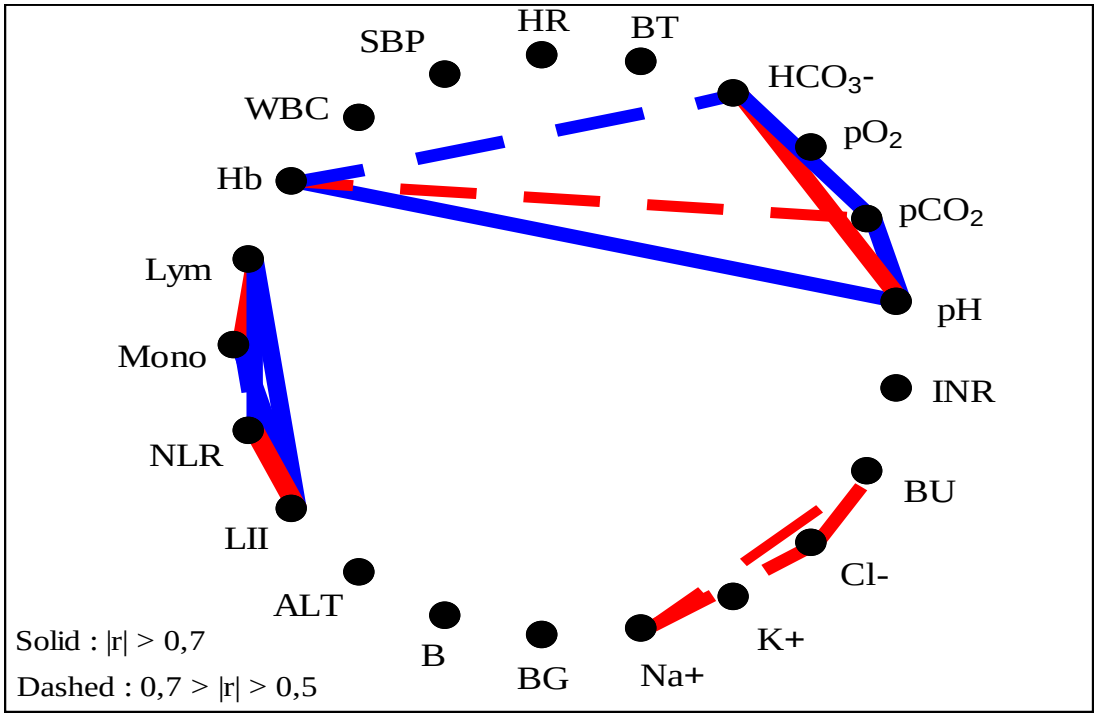


Figure 4. A cross-section diagram of the correlation cylinder at the levels |r| = 0.5 and |r| = 0.7 (for patients with an unfavourable outcome on the last day before the outcome). The thickness of the lines is proportional to |r| [cited by: 35, p. 15].

The selected three factors can be considered as a 'macro portrait' that characterises the physiological status of the patient on the last day before the onset of an unfavourable outcome. The interpretation of these factors is given below:

1. The first factor is represented by four signs: Leukocyte Intoxication Index (LII), Neutrophil-Lymphocyte Ratio (NLR), absolute number of lymphocytes (Lym) and monocytes (Mono). This factor reflects the nature of the morphological relationships of the main cells of the immune system and the severity of general intoxication of the body and infectious complications. The frequency and distribution of infectious complications in the studied group of patients are given in Table 17.

Table 17. The frequency of infectious complications in the studied group of patients (n=23)

Indicator	Number of patients, n=23	
	absolute number	%
Infectious complications	23	100
Pneumonia	21	91.3
Sepsis, severe sepsis, septic shock	11	47.8
Meningitis, meningoencephalitis	8	34.8
Sinusitis, polysinusitis	4	17.4
Cystopyelonephritis	2	8.7
Peri-mandibular phlegmons	2	8.7
Tracheobronchitis, endobronchitis	1	4.3
Other infectious complications	2	8.7

2. The second factor includes four signs: blood acidity level (pH), partial pressure of carbon dioxide in arterial blood (pCO2), blood bicarbonate level (HCO3-), and haemoglobin level (Hb). The second factor reflects the acid-base state and the adequacy of pulmonary ventilation and tissue oxygenation.

Depending on the type, severity, and origin of the violation of the acid-base state, it is possible to determine the nature of functional disorders of the body systems that provoke this violation. A violation of the acid-base state of metabolic origin indicates the intensity of the process of tissue destruction, while the respiratory origin of these disorders indicates a violation of pulmonary ventilation and tissue oxygenation.

Acute acidosis (pH <7.35) was observed in 9 out of 23 patients (39.1%). Mixed acute acidosis (respiratory (pCO2 >48 mmHg) and metabolic (HCO3-<22.2 mmol/L)) was observed in 5 out of 9 patients (55.6%). Metabolic acute acidosis was observed in 4 patients (44.4%).

Acute alkalosis (pH >7.45) was observed only in 4 out of 23 patients (17.4%). A mixed type of acute alkalosis (respiratory (pCO2 <32 mmHg) and metabolic (HCO3- >28.3 mmol/L)) was observed in one patient (25%). Respiratory type of acute alkalosis was observed in three patients (75%).

Thus, violations of the acid-base state (acidosis or alkalosis) were observed in 13 out of 23 patients (56.5%). These violations indicate severe metabolic disorders in the body of the patients in 10 out of 13 (76.9%) cases and respiratory disorders in 9 cases (69.2%) (a mixed type of acid-base disorder was found in 6 patients).

In addition to the acid-base state component, there is also a respiratory component in the second factor. The main causes of hypoxemia are anemia and impaired blood oxygenation in the lungs due to a decrease in pO2. Anemia in the last day before the outcome occurred in all the patients. Mild anemia (haemoglobin = 90-119 g/l) was noted in 9 out of 23 patients (39.1%). Moderate anemia (haemoglobin = 70-89 g /l) - in 13 (56.5%); and severe anemia (haemoglobin <70 g/l) - in one patient (4.3%).

Hypoxemia (pO2 <75 mmHg) was observed in 9 out of 23 patients (39.1%), hyperoxemia (pO2 >120 mmHg) - in 10 (43.5%). It should be noted that hyperoxemia occurs as a result of intensive oxygen therapy, which is carried out in order to increase the saturation of haemoglobin with oxygen. However, in patients with anemia, this approach does not always lead to an improvement in SO2, and only to an increase in the concentration of oxygen dissolved in plasma. Respiratory failure of the first type (pO2 <60 mmHg and pCO2 50 <mmHg) was noted in five patients, and of the second type (pO2 <60 mmHg and pCO2 >50 mmHg) only in one. In general, respiratory system dysfunction was observed in 19 out of 23 patients (82.6%).

3. The third factor is represented by three signs: the concentration of sodium ions (Na+), chlorine ions (Cl-), and the level of urea (BU) in the blood. This factor reflects the functional state of the excretory system and the state of water-electrolyte metabolism.

Hypernatremia (Na+>145mmol/L) was observed in 17 out of 23 patients (73.9%); and hyponatremia (Na+<136 mmol/L) - in three (13%). Hyperchloremia (Cl->107 mmol/L) was observed in 17 patients (73.9%); and hyperchloremia - only in one (4.3%). An increase in the concentration of urea in the blood above the physiological norm (9.2 mmol/L) was observed in 13 patients (56.5%). It should be noted that hypovolemia and/or excessive infusion therapy with sodium chloride solutions could be the causes of impaired concentrations of sodium and chlorine ions in the blood. For this reason, changes in the concentration of Na+ and Cl- in the blood are considered indirect signs of impaired function of the excretory system. However, the direct correlation of the concentrations of these ions with the level of urea in the blood (r (Na+) = 0.5; r (Cl-) = 0.64) allows us to conclude that these violations are associated, among other things, with a violation of the function of the excretory system.

After the allocation of three factors, the 'scores' of each factor were calculated for the patients of the first subset of observations at each of the time points (days 1, 3, 7, and 14). The calculation of factor scores by this approach allows us to study the selected factors in dynamics. It is known that the dynamics of the average values of signs and average variances reflect the nature of the course of the pathological process [39, 46]. Based on the results of a comparative analysis of the scores of a certain factor in dynamics among patients with favourable and unfavourable outcomes, it is possible to assess the significance of this factor (and the signs forming it) for assessing the severity of the physiological status of the patients in the observation subset. The number of patients whose factor scores were calculated in dynamics is presented in Table 18. Only patients treated in the ICU wards at each of the time points were included in the analysis at this stage.

Table 18. The number of patients when calculating the scores of factors in dynamics

Time point	Number of patients					
	Total		Favourable outcome		Unfavourable outcome	
	absolute	%	absolute	%	absolute	%
Day 1	42	100	16	38.1	26	61.9
Day 3	40	100	14	35.0	26	65.0
Day 7	30	100	10	33.3	20	66.7
Day 14	14	100	4	28.6	10	41.4

Figures 5, 6, and 7 show the dynamics of the scores of the selected three factors on days 1, 3, 7, and 14 in patients with favourable and unfavourable outcomes, as well as on the last day before the outcome in patients with an unfavourable outcome.

Visual analysis of Figure 5 shows that the average values of the scores of the first factor in the group of patients with an unfavourable outcome are greater than those in the group of patients with a favourable outcome at all time points. The variance of the scores of the first factor on the first day is significantly greater in the group of patients with an unfavourable outcome. The greatest variance of the scores of the first factor is observed in patients with an unfavourable outcome on the last day before the onset of an unfavourable outcome.

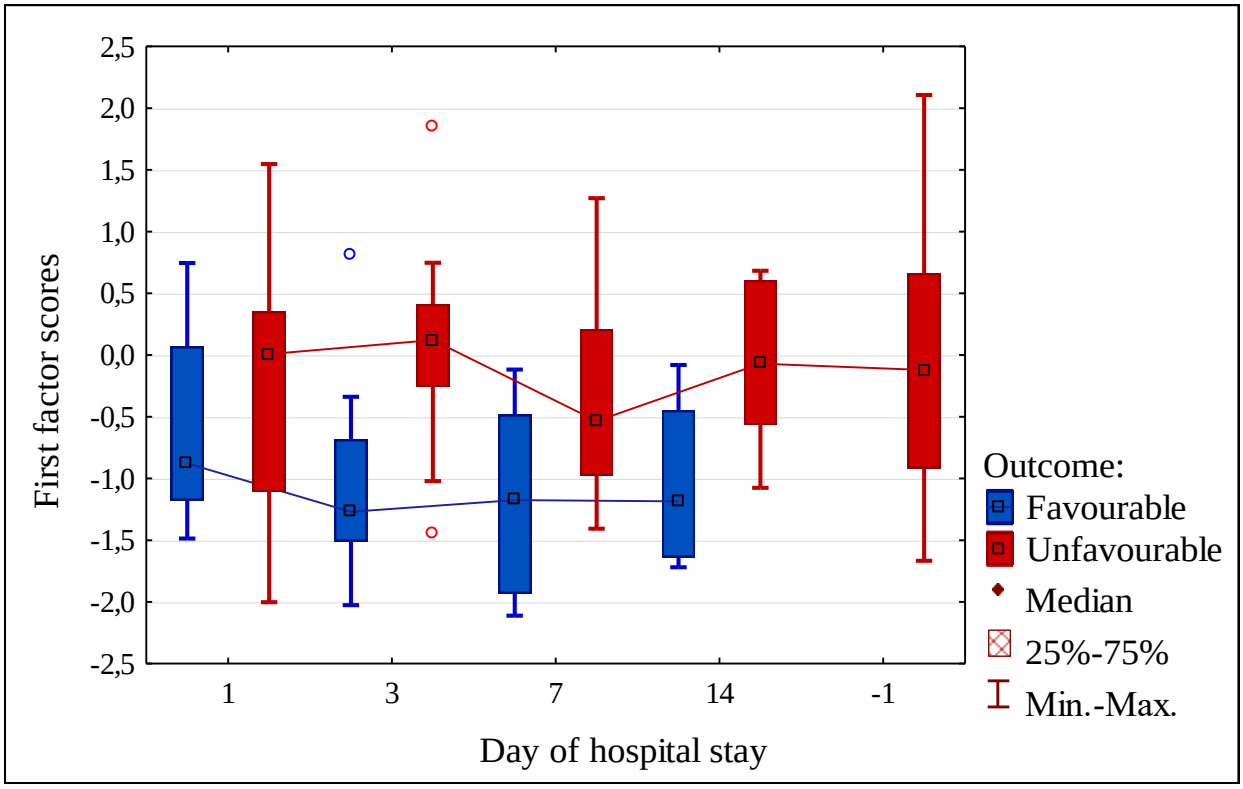


Figure 5. Diagram of the dynamics of the scores of the first factor.

In Figure 6, it can be seen that the differences in the average values of the scores of the second factor in the groups are insignificant and most pronounced on the first day after the injury. The variance of the scores of the second factor on the first and seventh day in the group of patients with an unfavourable outcome is greater than those in the group of patients with a favourable outcome. On the third day, the variance of the scores of the second factor is slightly higher in patients with a favourable outcome. The greatest variance of the scores of the second factor is observed on the last day before the outcome in the patients with an unfavourable outcome.

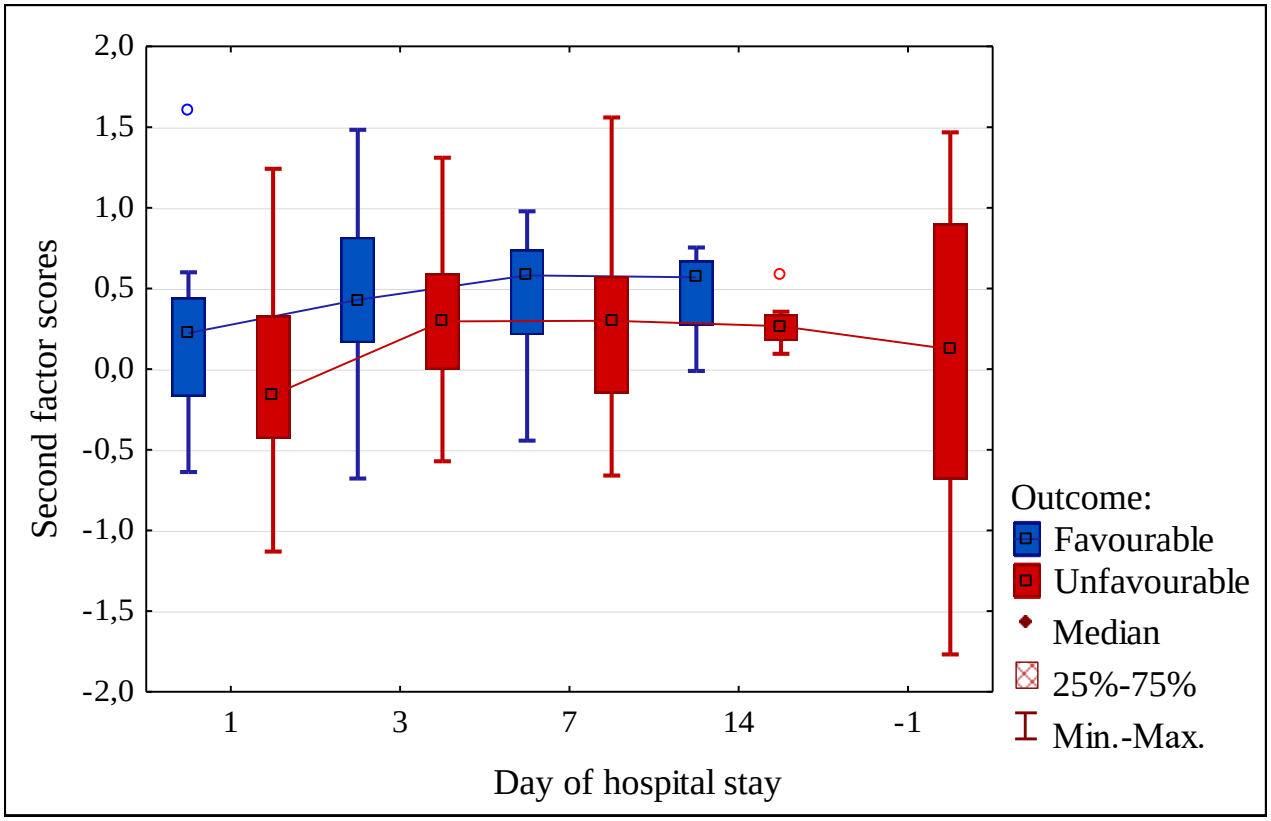


Figure 6. Diagram of the dynamics of the scores of the second factor.

Differences in the average values of the scores of the third factor in the groups are most pronounced on the third and seventh days. These differences increase on the third and seventh days and decrease on the fourteenth. The variance of the scores of the third factor in the group of patients with an unfavourable outcome on the first and seventh days is greater than that in the group of patients with a favourable outcome. As well as the variance of the scores of the first and second factors, the greatest variance of the scores of the third factor is observed in the group of patients with an unfavourable outcome on the last day before the onset of an unfavourable outcome (Figure 7).

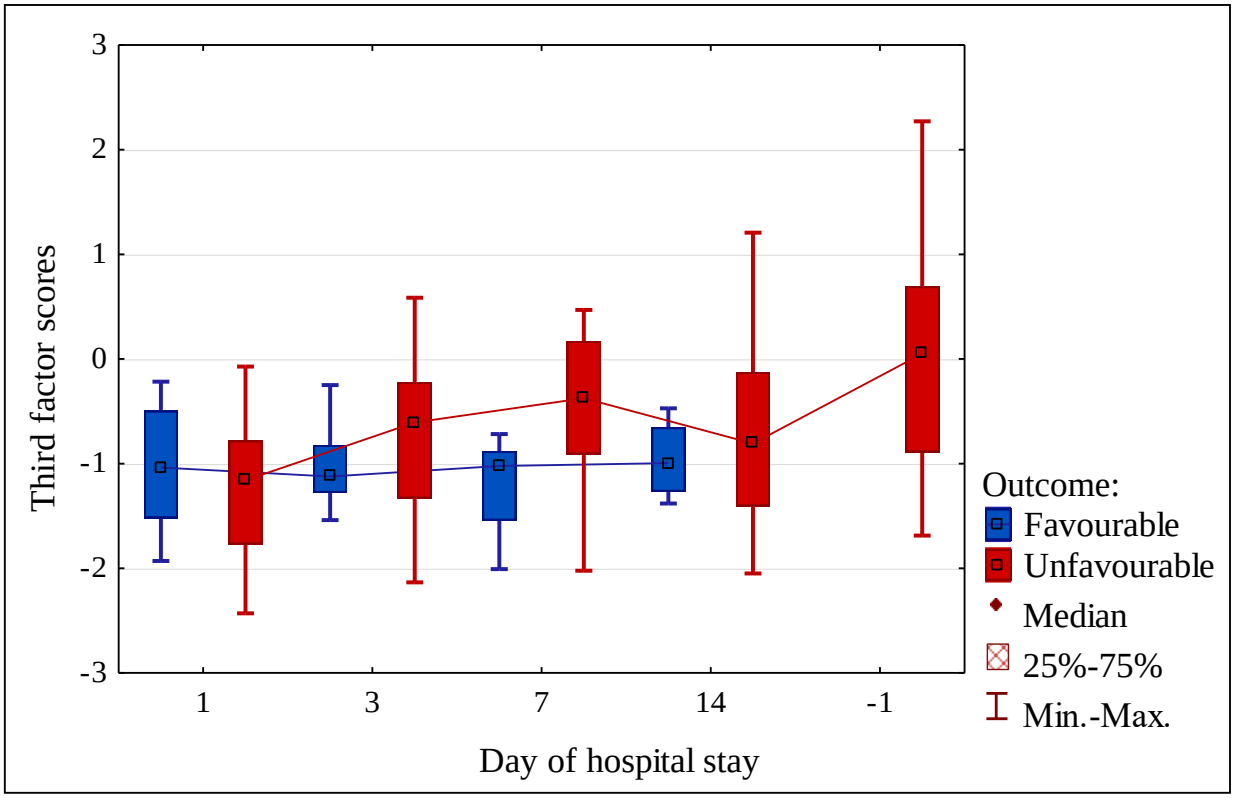


Figure 7. Diagram of the dynamics of the scores of the third factor.

To test the hypothesis of equality of the mean values of the factor scores in the groups, Student's t-test for independent groups was used. The presence of statistically significant differences in the mean values of the first factor on the third (p= 0.000), seventh (p= 0.013), and fourteenth days (p= 0.029) was established. It was also found that there were statistically significant differences in the average values of the third factor only on the seventh day (p= 0.009). In all other cases, the differences were statistically insignificant. These results are presented in Table 19.

Table 19. Comparative analysis of the average values of factor scores in patients with favourable and unfavourable outcomes

Factor	Time point (p-level)			
	Day 1	Day 3	Day 7	Day 14
Factor 1	0.190	**0.000**	**0.013**	**0.029**
Factor 2	0.116	0.227	0.512	0.564
Factor 3	0.398	0.104	**0.009**	0.228

Based on a visual analysis of the dynamics diagrams of scores of the selected factors, as well as a comparative analysis of the average values of the scores of the factors, it can be concluded that the separation of the groups of the first subset of observations, depending on the nearest outcomes, is most clearly based on the first factor.

Further analysis was aimed at studying the signs forming the first factor (LII, NLR, Mono, Lym) separately. Table 20 shows data on the number of patients in whom these signs were measured at each of the time points.

Table 20. The number of patients in the comparative analysis of the signs making the first factor

Time point	Number of patients					
	Total		Favourable outcome		Unfavourable outcome	
	absolute	%	absolute	%	absolute	%
Day 1	60	100	29	48.3	31	51.7
Day 3	55	100	25	45.5	30	54.5
Day 7	45	100	21	46.7	24	53.3
Day 14	27	100	13	48.1	14	51.9
Day -1	29	100	-	-	29	100

Figure 8 shows a diagram of the dynamics of absolute numbers of lymphocytes. Statistically significant differences in the mean values of this sign among the patients with favourable and unfavourable outcomes were observed on Day 1 (p= 0.001) and 3 (p= 0.000). On Days 7 and 14, the differences in averages were statistically insignificant (p=0.086 and 0.082, respectively). The greatest variance of the values of the Lym sign is observed on Day 1.

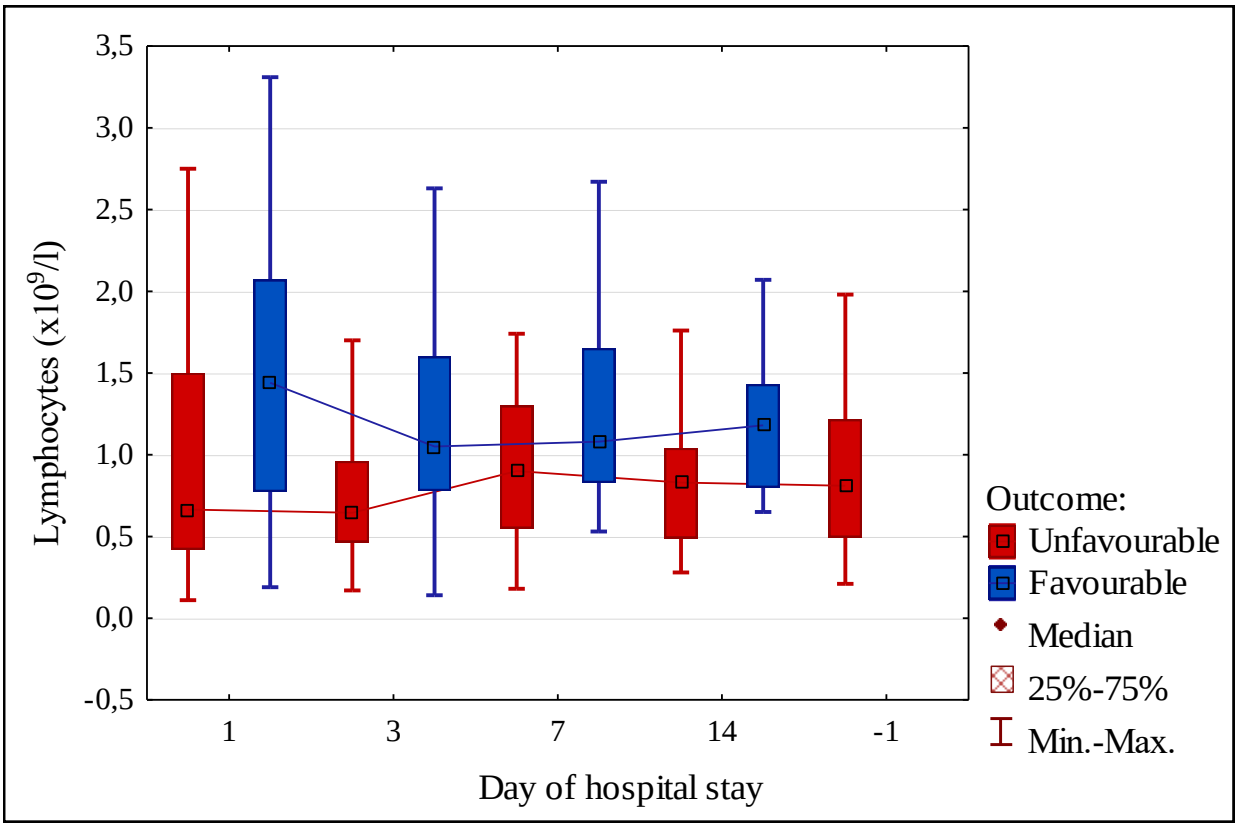


Figure 8. Diagram of dynamics of absolute numbers of lymphocytes.

Figure 9 shows a diagram of the dynamics of absolute numbers of monocytes. The differences in the average values of this sign by comparison groups turned out to be statistically insignificant on Days 1 (p=0.141) and 3 (0.074) days; and significant on days 7 and 14 (p=0.024 and 0.022, respectively). The greatest variance in the absolute number of monocytes can be seen on Day 7 after the injury.

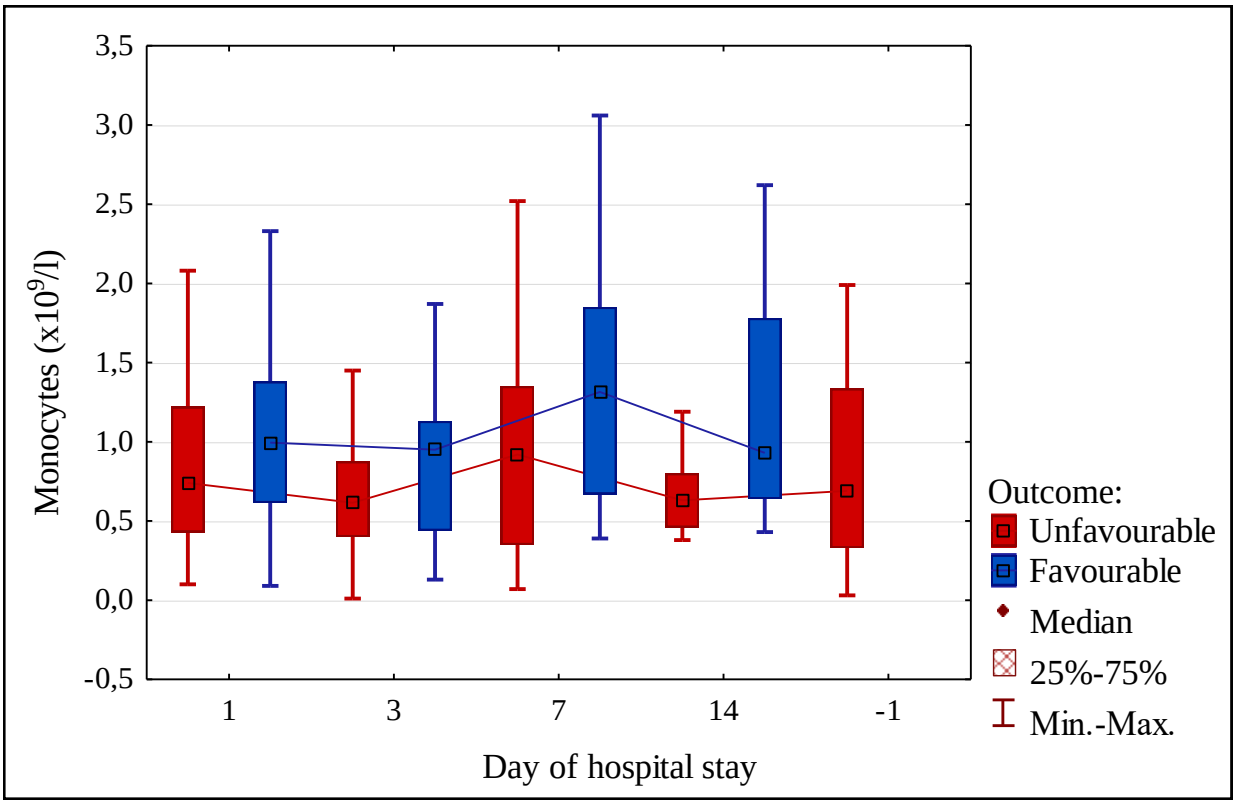


Figure 9. Diagram of the dynamics of absolute numbers of monocytes.

Figure 10 shows a diagram of the dynamics of the values of the Neutrophil-Lymphocyte Ratio. Statistically significant differences in the mean values of this sign among the patients with favourable and unfavourable outcomes were observed on Day 1 (p= 0.012), 3 (p= 0.000), and 7 (p=0.005). On Day 14, the differences in means were statistically insignificant (p= 0.059). The greatest variance in the values of the NLR sign is observed on Day 1 in the group of patients with an unfavourable outcome.

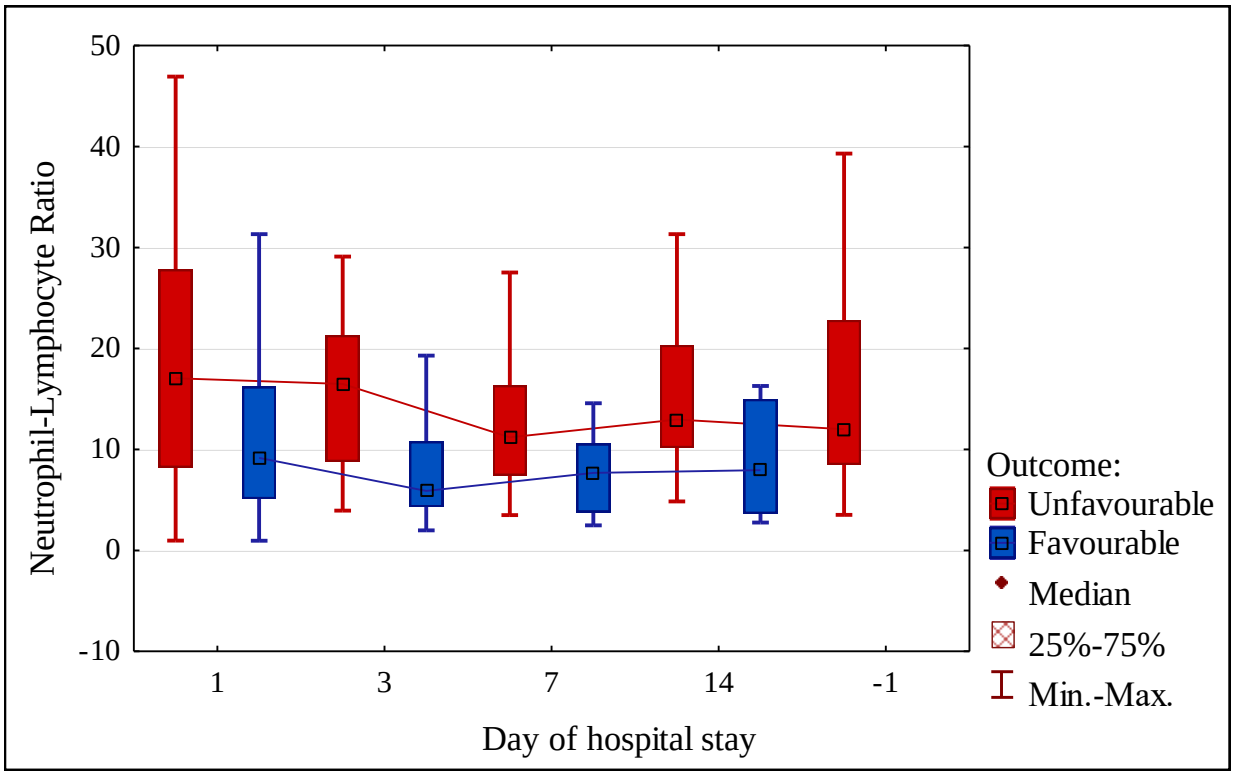


Figure 10. Diagram of the dynamics of the values of the Neutrophil-Lymphocyte Ratio.

A diagram of the dynamics of values of the leukocyte intoxication index is shown in Figure 11. Differences in the average values of this sign by comparison groups turned out to be statistically significant at all time points during the course of the traumatic disease. The greatest variance in the values of the LII sign is observed on the last day before the unfavourable outcome. The results of testing the hypothesis of the equality of the mean values of the signs of Lym, Mono, NLR, and LII among the patients with favourable and unfavourable outcomes using the Mann-Whitney test are presented in Table 21.

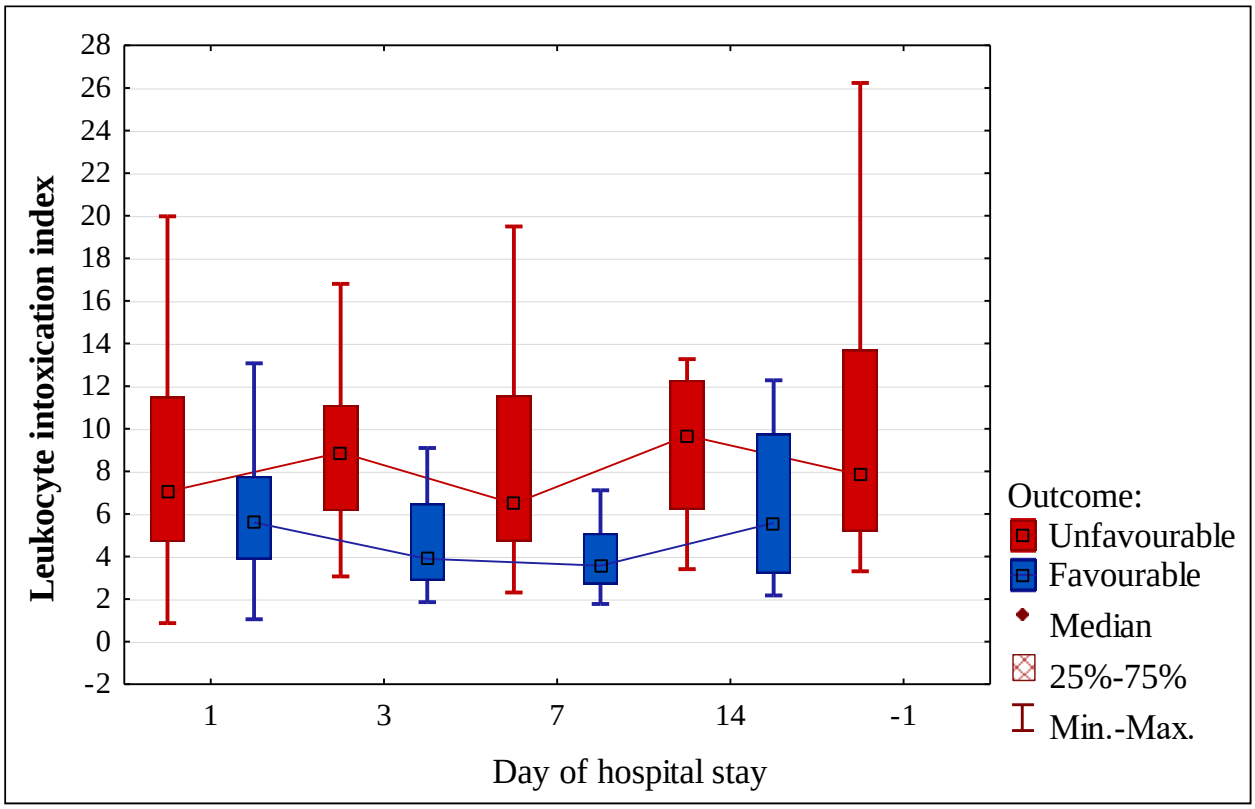


Figure 11. Diagram of the dynamics of values of the leukocyte intoxication index.

Table 21. The results of testing the hypothesis about the equality of the mean values of the signs of Lym, Mono, NLR, and LII in patients with favourable and unfavourable outcomes

Time point	Sign		Mann-Whitney test, (p=)	Time point	Sign		Mann-Whitney test, (p=)
	No.	Code			No.	Code	
Day 1	6	Lym	**0.001**	Day 7	6	Lym	0.086
	7	Mono	0.141		7	Mono	**0.024**
	8	NLR	**0.012**		8	NLR	**0.005**
	9	LII	**0.029**		9	LII	**0.000**
Day 3	6	Lym	**0.000**	Day 14	6	Lym	0.082
	7	Mono	0.074		7	Mono	**0.022**
	8	NLR	**0.000**		8	NLR	0.059
	9	LII	**0.000**		9	LII	**0.037**

Thus, based on the comparative analysis carried out, it can be concluded that the separation of the groups of the subset of observations depending on the immediate

outcomes is most clearly determined by the first factor, which includes the following four signs: absolute numbers of lymphocytes and monocytes, NLR, and LII. This factor reflects the nature of the morphological relationships of the main cells of the immune system and the severity of general intoxication of the body and infectious complications. Further analysis of the signs forming the first factor showed that statistically significant differences in the mean values among the patients with favourable and unfavourable outcomes simultaneously on days 1, 3, 7, and 14 were observed only in the LII sign.

The most common infectious complications among the patients of the retrospective data subset were pneumonia and meningitis. Pneumonia was diagnosed in 36 (57.1%) patients; meningitis (serous and purulent) - in 11 (17.5%) patients. Taking into account the results we obtained, further analysis was aimed at developing a mathematical model for predicting the probability of developing visceral infectious complications. The analysis included 9 features: features that form the first factor (Lym, Mono, NLR and LII) on the 1st and 3rd days of hospital stay, as well as the severity of injuries according to the MFS - I (MT) scale. The model was developed using the statistical analysis method - linear discriminant analysis (LDA). Table 22 presents descriptive statistics of the values of the features included in the LDA and the results of checking the significance of differences in their medians in the groups.

Table 22. Descriptive statistics of features included in LDA

Sign		Visceral infectious complications (pneumonia, meningitis)				Mann-Whitney test, (p=)
		yes (n=36)		No (n=27)		
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
6	Lym (1st day)	33	0,78 [0,11; 2,75]	25	1,54 [0,37; 2,67]	**0,001**
7	Mono (1st day)	33	0,75 [0,10; 2,14]	25	0,97 [0,09; 2,03]	0,351
8	NLR (1st day)	33	14,20 [0,98; 46,83]	25	8,42 [1,96; 31,33]	**0,005**
9	LII (1st day)	33	6,89 [1,00; 17,42]	25	5,29 [2,21; 12,56]	**0,016**
6	Lym (3rd day)	35	0,70 [0,14; 1,70]	24	1,45 [0,51; 2,63]	**0,000**
7	Mono(3rd day)	35	0,68 [0,05; 1,44]	24	0,97 [0,13; 1,87]	0,138

Continuation of Table 22

8	NLR (3rd day)	35	14,64 [3,94; 29,10]	24	5,81 [1,99; 19,29]	**0,000**
9	LII (3rd day)	35	7,61 [2,45; 16,30]	24	3,95 [1,86; 8,61]	**0,000**
-	MFS - I (MT)	36	12,35 [1,35; 24,10]	27	2,73 [1,00; 19,20]	**0,000**

As can be seen from Table 22, the differences in the medians of 7 of the 9 features are statistically significant. The step-by-step DA procedure with inclusion retained 3 of the 7 features: the absolute number of lymphocytes and the leukocyte intoxication index on the 3rd day of hospital stay and the severity of injuries according to the MFS - I (MT) scale. The developed model is significant and reliable ($p < 0.000$). The classification by the sample was 84.9%. Table 23 presents a list of features of the linear discriminant function (LDF), their coefficients and the level of significance.

Table 23. Features included in the model, their coefficients and significance level

Sign	LDF code	LDF 1 coefficients	LDF 2 coefficients	p-level
Lym (3rd day)	X_1	7,01	9,09	0,03
LII (3rd day)	X_2	1,34	1,07	0,07
MFS - I (MT)	X_3	0,31	0,17	0,03
Constant		-10,42	-10,24	-

The calculation of the prognosis of visceral infectious complications is carried out according to the following method:

1. Calculation of the linear discriminant function (LDF) using two formulas:

$$LDF_1 = 7{,}01X_1 + 1{,}34X_2 + 0{,}31X_3 - 10{,}42$$
$$LDF_2 = 9{,}09X_1 + 1{,}07X_2 + 0{,}17X_3 - 10{,}24 \quad (3)$$

Where X_1 – absolute lymphocyte count on 3rd day ($X_1 \times 10^9$/L);

X_2 – LII on 3rd day;

X_3 – severity of injuries according to the MFS - I (MT) scale.

2. Statistical decision rule: if the LDF1 value> LDF2 value, then the prognosis for the development of infectious complications is positive; if the LDF2 value> LDF1 value, then the prognosis is negative.

Below is the method of calculating the prognosis of the development of visceral infectious complications of a patients from the retrospective dataset:

Patient K., 25 years old, was delivered to the clinic on 10.02.2017 by an ambulance team. The injury was caused by a fall from a height of over 4 meters. The patient was diagnosed with: Catatrauma. Combined injury. Closed spinal cord injury. Compression-comminuted fracture of the 1st lumbar vertebra (L1) with damage to the spinal cord with lower paraplegia. Compression fracture of the body of the 9th thoracic vertebra (Th9). Open craniocerebral injury. Moderate brain contusion with the formation of a contusion-hemorrhagic focus in the left frontal lobe. Subarachnoid hemorrhage. Fracture of the occipital bone with transition to the base in the area of the posterior cranial fossa. Fracture of the right temporal bone with transition to the base of the skull in the area of the middle cranial fossa. Fracture of the sphenoid bone. Fracture of the lateral and inferior walls of the left orbit. Pneumocephalus. Closed chest injury. Closed fractures of the ribs VI-VIII on the right with displacement of fragments, V-VIII ribs on the left. Hemopneumothorax on both sides. Contusion of the lungs. Contusion of the heart. Contusion of the kidneys.

According to the medical history data, on 17.02.2017 (on the 7th day after the trauma), the patient was diagnosed with bilateral lower lobe pneumonia. Table 24 presents the calculation method for the prognosis of the development of visceral infectious complications in the patient K. according to the presented model. As can be seen from the table, the LDF1 value is > the LDF2 value. In accordance with the statistical decision rule, the prognosis of the development of visceral infectious complications is assessed as positive.

Table 24. Calculation of the prognosis for the development of visceral infectious complications in patient K.

Sign	Value	LDF 1		LDF 2	
		Coefficients	Score	Coefficients	Score
Lym (3rd day)	0,84	7,01	5,89	9,09	7,64
LII (3rd day)	6,76	1,34	9,06	1,07	7,23
MFS - I (MT)	13,5	0,31	4,19	0,17	2,30
Constant	-	-10,42	-10,42	-10,24	-10,24
Sum	-	-	8,71	-	6,92

The developed model is easy to use, the signs of LDF are available for determination, the model allows for a highly accurate prediction of the probability of developing visceral infectious complications on the 3rd day after the injury. With a positive prognosis, it is recommended to implement the entire complex of advanced therapy tactic of multi-stage surgical treatment [25].

3.2. Assessment of the combined midface trauma severity in the third period of traumatic disease based on objective determinants of severity

The third period of traumatic disease begins on the 3rd day after the injury and continues for 10-12 days. According to the theory and concept of traumatic disease, this period is characterized by the maximum probability of developing post-traumatic complications [25]. As was already established in the previous part of the clinical and biometric analysis and taking into account the inclusion and exclusion criteria in our study, infectious complications have the greatest contribution to determining the immediate outcomes of combined midface trauma. This statement emphasizes the significant importance of clinical decisions made in this period. One of the main tasks of assessing the severity of injury in this period is to justify the adoption of these clinical decisions. On the other hand, solving this problem on the 3rd day after the injury becomes more difficult due to the "blurring" of the clinical picture due to the already initiated treatment process and the inaccessibility of a number of signs for

assessment. The objective of this part of the clinical and biometric analysis is to identify determinants of injury severity and develop a mathematical model for classifying patients in the intensive care units on the 3rd day of inpatient treatment.

In accordance with the expert assessment of the trauma severity (severity of injuries and physiological status) on the 3rd day of hospital stay, the patients of the retrospective subset (n=63) were assigned to one of two groups: the first group (corresponding to severe injury) includes 30 (47.6%) patients; the second group (corresponding to extremely severe injury) - 33 (52.4%) patients. In the comparative analysis of the groups, the following 16 characteristics were assessed: data on the presence of cardiovascular disease (CVD), the occurrence of cerebral edema (CE) and traumatic shock (TSh), the severity of traumatic shock (if it in its exist), the estimated amount of blood loss, the patient age, the value of the shock index on admission (Sh-I), the severity of injuries according to the MFS - I (MT) scale, the heart rate, systolic blood pressure, hemoglobin level, the absolute number of leukocytes, lymphocytes and monocytes, as well as the values of the neutrophil-lymphocyte ratio and the leukocyte intoxication index.

Analysis of the table of the incidence rates of cerebral edema in the groups showed that this complication was diagnosed in 23 (69.7%) patients of the second group, and only in one (3.3%) patient of the first group. Testing the hypothesis of the absence of a difference in the frequencies of this feature in the groups using Fisher's exact test showed that this difference is statistically significant (p=0.000). Table 25 shows the distribution of the cerebral edema feature in the groups and the significance level of the difference in its frequencies.

Table 25. Distribution of the Cerebral edema in groups and the level of significance of the difference in its frequencies

Group	Cerebral edema		Total	P-level (Fisher criterion)
	Yes	No		
1st, abs. num.	1	29	30	**0,000**
% by column	4,17%	74,36%	-	
2nd, abs. num.	23	10	33	
% by column	95,83%	25,64%	-	
Total	24	39	63	

Cardiovascular diseases were present in the anamnesis of 10 of 29 (34.5%) patients of the first group and in 20 of 32 patients (62.5%) of the second group. In the medical records of 2 patients of the retrospective subset, there were no data on CVD in the anamnesis. The difference in the frequencies of CVD in the groups is statistically significant (p for $\chi 2 = 0.029$). Table 26 presents the frequencies of CVD in the groups and the level of significance of their difference.

Table 26. Frequencies of CVD and the level of significance of their differences in groups

Group	Cardiovascular diseases		Total	Pearson $\chi 2$; P-level
	Yes	No		
1st, abs. num.	10	19	29	**4,78; 0,029**
% by column	33,33%	61,29%	-	
2nd, abs. num.	20	12	32	
% by column	66,67%	38,71%	-	
Total	30	31	61	

Traumatic shock on admission to hospital was diagnosed in 18 (60%) of the first group patients and in 93.9% of the second group patients. A statistically significant difference in the incidence of traumatic shock in the groups was established. The P-level of significance of this difference according to Fisher's exact criterion was 0.001. These results are presented in Table 27.

Table 27. Frequencies of development of traumatic shock in the groups and the level of significance of their differences

Group	Traumatic shock on admission		Total	P-level (Fisher criterion)
	Yes	No		
1st, abs. num.	18	12	30	**0,001**
% by column	36,73%	85,71%	-	
2nd, abs. num.	31	2	33	
% by column	63,27%	14,29%	-	
Total	49	14	63	

Among 49 patients of the retrospective subset, the first degree of severity of traumatic shock was diagnosed in 4 (22.2%) patients of the first group and in 13 (41.9%) patients of the second; the second degree - in 10 (55.6%) patients of the first group and in 14 (45.2%) patients of the second; the third degree of severity in 4 (22.2%; 12.9%) patients of the first and second groups, respectively. The difference in the frequencies of the severity of traumatic shock in the groups is statistically insignificant (p for $\chi 2 = 0.344$). Distribution of patients by the severity of traumatic shock in the groups presented in Table 28.

Table 28. Distribution of patients in the groups by the severity of traumatic shock and the level of significance of the differences in the frequencies of the feature

Group	Severity of traumatic shock			Total	Pearson $\chi 2$; P-level
	I	II	III		
1st, abs. num.	4	10	4	18	2,13; 0,344
% by column	23,53%	41,67%	50,00%	-	
2nd, abs. num.	13	14	4	31	
% by column	76,47%	58,33%	50,00%	-	
Total	17	24	8	49	

Testing the null hypothesis of equality of frequencies of the "estimated blood loss" feature in the groups using the Pearson $\chi 2$ criterion showed that the difference in frequencies in the groups is statistically significant (p= 0.006). Table 29 shows the

distribution of patients by estimated blood loss in the groups and the significance level of the difference in their frequencies.

Table 29. Distribution of patients by estimated blood loss in groups and the level of significance of differences in their frequencies

Group	estimated blood loss				Total	Pearson $\chi 2$; P-level
	up to 0.5 l	0.5-1.0 l	1.0-1.5 l	more than 1.5 l		
1st, abs. num.	12	4	10	4	30	**12,46; 0,006**
% by column	85,71%	23,53%	41,67%	50,00%	-	
2nd, abs. num.	2	13	14	4	33	
% by column	14,29%	76,47%	58,33%	50,00%	-	
Total	14	17	24	8	63	

Table 30 presents descriptive statistics and the results of a comparative analysis of medians using the Mann-Whitney test for 11 features included in the analysis. The presence of statistically significant ($p< 0.05$) differences in medians in the groups was registered for the following features: hemoglobin level, absolute lymphocyte count, neutrophil-lymphocyte ratio, leukocyte intoxication index, and severity of damage according to the MFS - I (MT) scale. The differences in medians for the remaining features are statistically insignificant ($p> 0.05$).

Table 30. Descriptive statistics of features and levels of significance of differences in their medians in the groups

Sign		1st group		2nd group		Mann-Whitney test, (p=)
No.	Code	n	Median [Min.; Max.]	n	Median [Min.; Max.]	
2	HR	30	93,00 [71,00; 130,00]	33	102,00 [68,00; 126,00]	0,236
3	SBP	30	120,00 [90,00; 140,00]	33	116,00 [80,00; 150,00]	0,561
4	Hb	20	100,00 [65,00; 145,00]	33	87,00 [64,00; 140,00]	**0,048**
5	WBC	21	9,87 [6,84; 15,44]	33	10,46 [4,31; 20,36]	0,643
6	Lym	20	1,05 [0,50; 2,63]	33	0,62 [0,14; 1,55]	**0,001**
7	Mono	20	0,94 [0,13; 1,87]	33	0,65 [0,05; 1,44]	0,083
8	NLR	20	6,80 [1,99; 19,29]	33	16,20 [3,94; 29,10]	**0,001**

Continuation of Table 30

9	LII	20	3,96 [1,86; 10,71]	33	7,72 [2,45; 16,30]	**0,000**
Age		30	45,00 [23,00; 86,00]	33	57,00 [25,00; 87,00]	0,122
TSh		30	0,98 [0,54; 1,59]	33	0,96 [0,48; 1,97]	0,589
MFS - I (MT)		30	2,85 [1,00; 19,20]	33	12,50 [1,35; 24,10]	**0,000**

Thus, the conducted analysis allowed us to conclude that the differences in the frequencies of the signs of CVD, CE, traumatic shock on admission and the estimated amount of blood loss in the groups are statistically significant, and also that the differences in the medians of the hemoglobin level, absolute lymphocyte count, neutrophil-lymphocyte ratio, leukocyte intoxication index and the severity of damage according to the MFS - I (MT) scale are statistically significant. These signs were used in conducting linear discriminant analysis (LDA).

The step-by-step DA procedure with inclusion retained 5 of 9 features: the absolute number of lymphocytes and the hemoglobin level on the 3rd day of hospital stay, the severity of injuries according to the MFS - I (MT) scale, the presence of CVD and the development of cerebral edema. The developed model is significant and reliable ($p < 0.00$). The classification by the sample was 90.4%. Table 31 presents a list of features included in this model, their coefficients, and the level of significance.

Table 31. Features included in the model, their coefficients and significance level

Sign	LDF code	LDF1 coefficients	LDF2 coefficients	p-level
CE	X_1	14,14	10,04	0,001
MFS - I (MT)	X_2	0,06	0,41	0,000
Lym (3rd day)	X_3	1,90	–0,11	0,050
CVD	X_4	5,99	4,56	0,146
Hb (3rd day)	X_5	0,28	0,24	0,184
Constant		–34,83	–24,02	-

The severity of the combined midface trauma is assessed using the following method:

1. Calculation of the linear discriminant function (LDF) using two formulas:

$$ЛДФ_1 = 14{,}14X_1 + 0{,}06X_2 + 1{,}90X_3 + 5{,}99X_4 + 0{,}28X_5 - 34{,}83$$
$$ЛДФ_2 = 10{,}04X_1 + 0{,}41X_2 - 0{,}11X_3 + 4{,}56X_4 + 0{,}24X_5 - 24{,}02 \quad (4)$$

Where X_1 – cerebral edema (yes- 1; no- 2);

X_2– severity of injury according to the MFS - I (MT) scale);

X_3– absolute lymphocyte count on day 3 ($X_3 \times 10^9$/л);

X_4– cardiovascular diseases (yes- 1; no- 2);

X_5 – hemoglobin level on day 3 (г/л).

2. Statistical decision rule: if LDF1 value > LDF2 value, then the injury is severe; if LDF2 value > LDF1 value, then the injury is extremely severe.

Below is the method for assessing the severity of combined midface trauma based on objective determinants of severity using the example of a patient from the retrospective dataset:

Patient S., 30 years old, was delivered to the clinic on 20.05.2017 by an ambulance team. The circumstances of the injury are unknown. The Patient was diagnosed with: Combined injury. Open craniocerebral injury. Severe brain contusion with the formation of a lamellar subdural hematoma over the right hemisphere of the brain. Massive subarachnoid hemorrhage. Secondary dyshemical disorders with the formation of ischemic zones in both hemispheres and the brainstem. Cerebral edema. Fracture of the base of the skull at the level of the middle cranial fossa. Otoliquorrhea on the left. Fracture of the lower wall of the left orbit. Hemosinus of the left maxillary sinus. Closed chest injury. Fracture of the VIII and IX ribs on the right. Right-sided hemopneumothorax. Contusion of the right lung. Contused wound of the frontal region. Multiple bruises, hematomas of the face, scalp, torso and limbs.

Table 32 presents the methodology for assessing the severity of the combined midface trauma the patient S. according to the presented model. As can be seen from the table, the value of LDF2 > the value of LDF1. According to the statistical decision rule, the severity of the injury of the patient is assessed as extremely severe.

Table 32. Assessment of the severity of the combined midface trauma (patient S.)

Sign	Value	LDF 1		LDF 2	
		Coefficients	Score	Coefficients	Score
CE	1	14,14	14,14	10,04	10,04
MFS - I (MT)	14,35	0,06	0,86	0,41	5,88
Lym (3rd day)	0,62	1,9	1,18	-0,11	-0,07
CVD	2	5,99	11,98	4,56	9,12
Hb (3rd day)	114	0,28	31,92	0,24	27,36
Constant	-	-	-34,83	-	-24,02
Sum	-	-	25,25	-	28,32

The developed model is easy to use, the signs of LDF are available. Classification of patients in the intensive care units by the severity of injury using this model does not require expensive analyses or the availability of special equipment, which makes the model accessible to hospitals of any level, regardless of their level of equipment.

CHAPTER 4.
METHODOLOGY FOR PREDICTING THE IMMEDIATE OUTCOMES OF COMCOMITANT MIDFACE TRAUMA

The currently existing methods and scales for predicting the outcome of injury have been developed to solve one or more specific tasks. Most often, these methods were intended to solve the problem of sorting the patients and determining the order of medical care at the pre-hospital or hospital stages. In such methods, the prognosis is calculated at the earliest possible time or during the first day after the injury.

In making the design of this study, the task of triage was not set, and the developed method for predicting immediate outcomes should be integrated into the algorithm for treating patients. The first question that was planned to be answered was what time point could be considered critical and therefore 'optimal' for making predictions, and at what time predicting the immediate outcome of this type of injury in general becomes possible. To solve this issue, a method of statistical analysis was applied - factor analysis (PCA) with the inclusion of a set of 22 physiological signs mentioned in the previous chapter, as well as the 'outcome' sign characterising the group affiliation of the patients (favourable or unfavourable outcomes). This analysis was carried out in a separate form with data collected on Days 1, 3, 7, and 14.

The conducted factor analysis showed that on Days 1, 7, and 14 the sign of group association 'outcome' got included in two or more factors. At that, the maximum factor load was 0.74. On Day 3, this sign was included only in the first factor with a factor load of 0.84. Based on these results, it can be concluded that, taking into account a set of physiological signs included in our work, the most optimal time point (critical point) for predicting the immediate outcomes of a concomitant midface trauma is the third day after the injury. The results of factor analysis with the values of signs for the third day are presented in Table 33. The number of patients included in this analysis on the third day was 36.

Table 33. Results of factor analysis on the third day after the injury

Sign		Factor							
No.	Code	1	2	3	4	5	6	7	8
-	Outcome	-0.84	0.31	-0.01	-0.1	-0.17	0.12	-0.18	0.14
1	BT	-0.19	-0.53	0.08	0.33	-0.25	-0.27	0.26	0.1
2	HR	-0.02	-0.04	-0.04	-0.27	-0.06	-0.84	-0.06	-0.1
3	SBP	-0.2	-0.03	-0.2	0.29	-0.01	-0.02	-0.63	-0.27
4	D	-0.34	-0.48	0.24	-0.45	0.08	0.32	0.16	-0.18
5	WBC	0.02	-0.5	0.44	0.29	0.59	0.04	0.1	0.11
6	Lym	-0.61	0.25	0.56	0.23	0.33	0.12	0.06	-0.12
7	Mono	-0.55	-0.17	0.37	0.45	0.34	-0.24	-0.02	0.01
8	NLR	0.61	-0.66	-0.29	-0.06	0.13	-0.05	-0.05	0.18
9	LII	0.71	-0.53	-0.23	-0.2	0.11	0.1	-0.03	0.14
10	ALT	-0.18	-0.22	-0.59	0.32	-0.34	0.19	0.26	-0.12
11	B	-0.44	-0.67	-0.02	0.11	-0.19	0.3	0.09	-0.09
12	BG	0.68	-0.05	0.21	0.3	-0.01	0.06	-0.06	-0.38
13	Na+	0.7	0.22	0.34	0.38	-0.03	0.15	0.17	0.07
14	K+	-0.46	-0.04	-0.23	-0.2	0.31	0.33	-0.29	0.34
15	Cl-	0.62	0.29	0.21	0.45	-0.13	0.09	-0.08	0.34
16	BU	0.29	-0.2	-0.02	-0.17	0.54	-0.19	-0.28	0.14
17	INR	0.48	0.03	-0.18	-0.04	0.35	0.16	-0.11	-0.62
18	pH	-0.58	0	-0.45	0.32	0.22	-0.17	0.28	-0.08
19	pCO2	0.6	0.44	0.15	-0.36	0.07	0.12	0.25	0.03
20	pO2	0.49	0.13	-0.48	0.38	0.12	-0.06	0.08	0.07
21	SO2	-0.16	0.32	-0.66	0.32	0.37	0.14	-0.06	0.08
22	HCO3-	-0.16	0.31	-0.29	-0.25	0.5	-0.08	0.53	-0.03
Accumulated share, %		24	36	47	56	64	70	75	80

The data used in the development of the methodology for predicting immediate outcomes are as follows: indicators of 22 physiological signs, the age of the patients, the severity of injuries on the scale of military field surgery - Injury (Mechanical Trauma), data on the development of cerebral oedema (CE) in the patients after injury and on their history of diseases of the cardiovascular system (CVD). The development of the forecasting methodology was carried out using the statistical analysis method - canonical linear discriminant analysis (CLDA).

Among the 22 physiological signs, signs of blood gas composition (SO2, pH, pCO2, HCO3-, pO2) were measured much less than others. This is due to the fact that this analysis was performed in intensive care wards, the high cost of this analysis, and various technical difficulties. For this reason, as well as to increase the availability of the developed forecasting methodology, discriminant analysis was carried out in two versions: with the inclusion of signs of blood gas composition and without them.

4.1. The First Variant of the Discriminant Function

The first variant of the discriminant analysis included the following signs: all 22 physiological signs (including signs of blood gas composition), the age of the patient, the severity of injuries on the MFS - I (MT) scale, the presence or absence of CVD in the anamnesis, and the development of CE after injury.

The step-by-step CLDA procedure (with inclusion) left 9 out of 26 signs. The first variant of CLDA included 40 patients. The classification in the sample was 100% (without inversions). The model is significant, reliable ($p < 0.00$). Table 34 presents codes, coefficients and factor loadings of the canonical linear discriminant function (CLDF) features. The classification of patients and the CLDF values are presented in Figure 12.

Table 34. Codes of Signs, coefficients and factor loadings of the CLDF (first variant) [36]

Sign	Code	Coefficients (CLDF)	Factor loads	p- level
CE	X_1	-2,17	-0,47	0,00
LII (on Day 3)	X_2	0,13	0,37	0,08
pO2 (on Day 3)	X_3	0,01	0,25	0,02
BG (on Day 3)	X_4	0,16	0,24	0,22
K+(on Day 3)	X_5	-1,12	-0,24	0,01
INR (on Day 3)	X_6	1,48	0,21	0,26
pCO2 (on Day 3)	X_7	0,04	0,18	0,18
CVD	X_8	-0,76	-0,18	0,24
Age	X_9	0,01	0,16	0,28
Constant	-	0,67	-	-

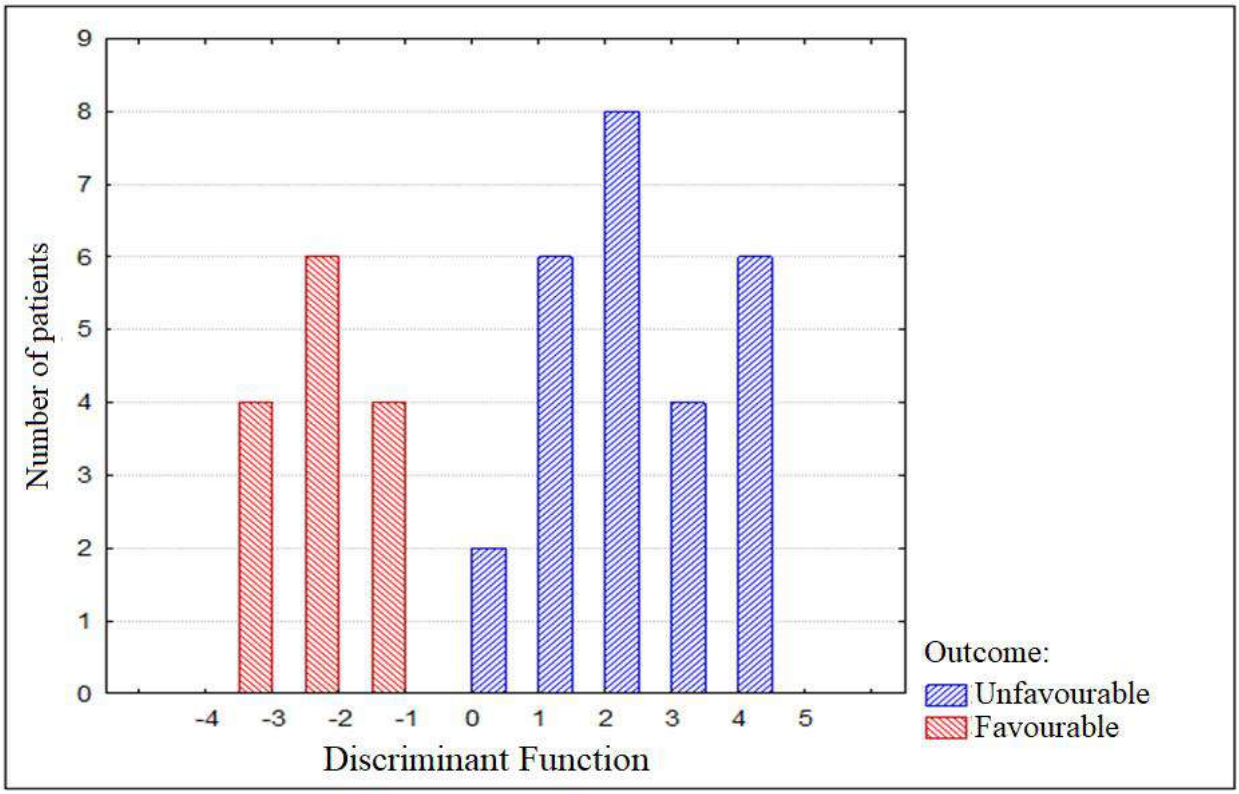


Figure 12. Histogram of CLDF values (first variant).

Calculation of the forecast of the trauma outcomes in the first variant of the CLDF is carried out according to the following methodology:

1. Calculation of the discriminant function by the formula:

$$CLDF = -2{,}17X_1 + 0{,}13X_2 + 0{,}01X_3 + 0{,}16X_4 - 1{,}12X_5 + 1{,}48X_6 + 0{,}04X_7 - 0{,}76X_8 + 0{,}01X_9 + 0{,}67 \quad (5)$$

Where X_1 – cerebral edema (yes- 1; no- 2);

X_2 – LII on the 3rd day;

X_3 – pO2 on the 3rd day (mmHg);

X_4 – blood glucose level on the 3rd day (mmol/l);

X_5 – concentration of potassium ions in the blood on the 3rd day (mmol/l);

X_6 – INR on the 3rd day;

X_7 – pCO2 on day 3 (mmHg);

X_8 – cardiovascular diseases (yes- 1; no- 2);

X_9 – age of the patient.

2. Statistical decisive rule: if CLDF <0, then the prognosis for the patient is considered favourable; if CLDF >0 – unfavourable.

Below is the method for calculating the prognosis of immediate trauma outcomes using the example of a patient from the retrospective dataset:

Patient Sh., 52 years old, was delivered to the clinic on 28.08.2017 by an ambulance team. Domestic injury. The patient was diagnosed with: Open craniocerebral injury. Severe brain contusion with compression by an acute subdural hematoma in the right frontal-temporal-parietal-occipital region. Subarachnoid hemorrhage. Basal skull fracture in the anterior cranial fossa. Upper, middle and lower fracture of the upper jaw. Contusions, hematomas of soft tissues of the head, face, chest, extremities. Emphysema of soft tissues of the face. Dislocation syndrome stage 2. According to the medical history, the patient died on 05.09.2017, on the 9th day after the injury. Table 35 presents the methodology for calculating the prognosis of the immediate outcomes for patient Sh. using the presented model. As can be seen from the table, the value of CLDF> 0. According to the statistical decision rule, the prognosis of the trauma outcome is assessed as unfavorable.

Table 35. Calculation of the immediate outcomes prognosis of the combined midface trauma (patient Sh.)

Sign	Value	Coefficients	Score
CE	1	-2,17	-2,17
LII (on Day 3)	7,52	0,13	0,9776
pO2 (on Day 3)	198	0,01	1,98
BG (on Day 3)	7,27	0,16	1,1632
K+(on Day 3)	4	-1,12	-4,48
INR (on Day 3)	1,04	1,48	1,5392
pCO2 (on Day 3)	38,7	0,04	1,548
CVD	1	-0,76	-0,76
Age	52	0,01	0,52
Constant	-	-	0,67
Sum	-	-	0,988

Among the signs included in the first variant of CLDF, the highest factor load was observed in the sign of CE (Table 34). With the development of such a severe complication in the patient, the probability of a fatal outcome seriously increases. The probability of a fatal outcome also increases with an increase in the values of the signs of LII, pO2, BG, INR, pCO2 and with a decrease in the values of K+ (measured on the third day after injury). The lowest factor loads were observed in signs of age and CVD. With an increase in the age of the patients and if they have a history of CVD, the probability of a fatal outcome also increases.

4.2. The Second Variant of the Discriminant Function

The second variant of the discriminant analysis included the following signs: 17 physiological signs (not included signs of blood gas composition: SO2, pH, pCO2, HCO3-, pO2), the age of the patient, the severity of damage on the MFS - I (MT) scale, the history of CVD in the anamnesis, and the development of CE after injury.

Step-by-step CLDA procedure (with inclusion) left 8 signs: WBC (on Day 1), log LII (on Day 3), K+ (on Day 3), log BU (on Day 3), log Lym (on Day 3), the development of CE, age, and CVD. The number of patients included in the analysis was 50. The classification in the sample was 98.0% (1 inversion). The model is significant and reliable ($p < 0.00$). Codes, coefficients and factor loadings of the CLDF features are presented in Table 36. The classification of patients and the KLDF values are presented in Figure 13.

Table 36. Codes of Signs, coefficients and factor loadings of CLDF (second variant) [36]

Sign	Code	Coefficients (CLDF)	Factor loads	p- level
Cerebral edema	X_1	-2,32	-0,49	0,00
log LII (on Day 3)	X_2	4,87	0,41	0,00
K+(on Day 3)	X_3	-1,01	-0,25	0,00
CVD	X_4	-1,19	-0,24	0,01
log BU (on Day 3)	X_5	2,44	0,22	0,00

Continuation of Table 36

Age	X_6	-0,02	0,22	0,22
log Lym (on Day 3)	X_7	2,65	-0,22	0,00
WBC (on Day 1)	X_8	-0,06	-0,10	0,10
Constant	-	6,68	-	-

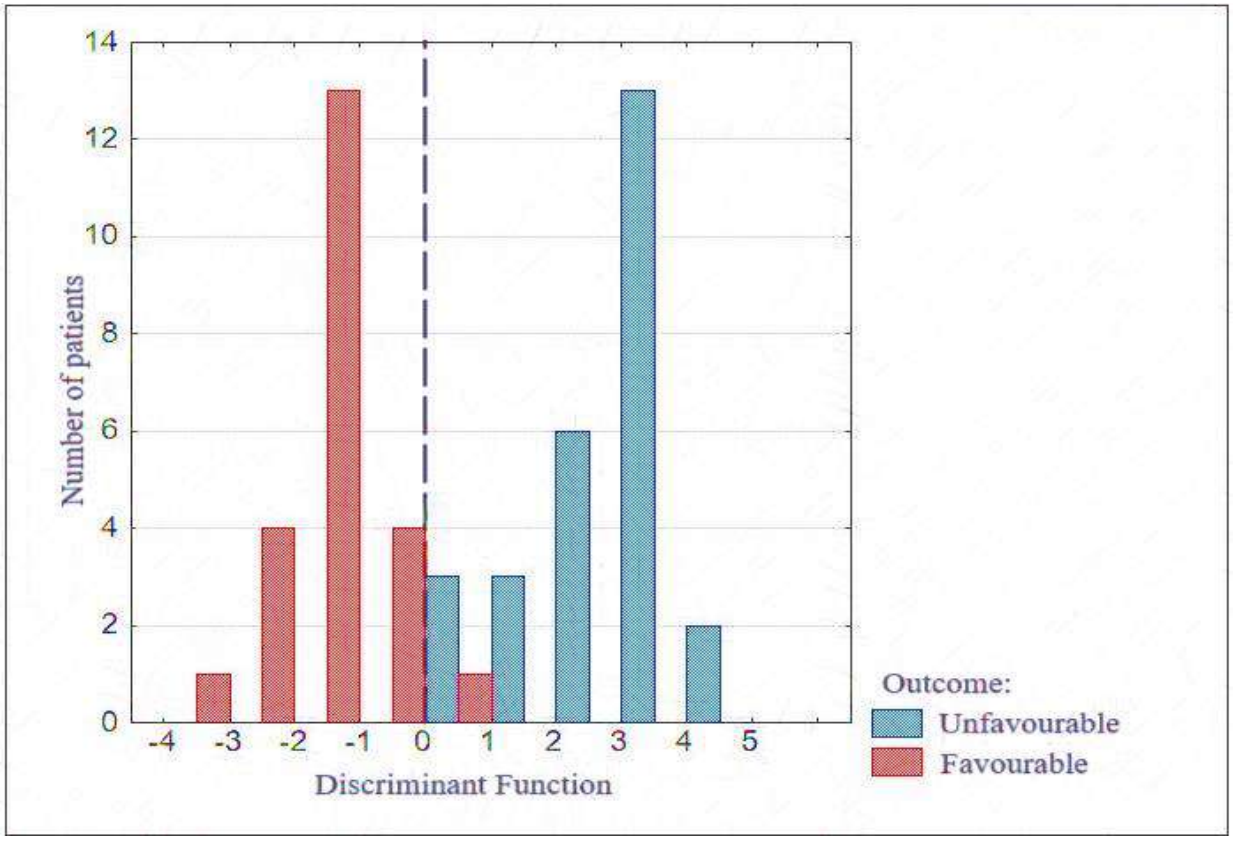


Figure 13. Histogram of DF values (second variant).

Calculation of the prognosis of the outcomes in the second variant of the CLDF is carried out according to the following method:

1. Calculation of the discriminant function using the formula:

$$CLDF= –2,32X1+ 4,87X2– 1,01X3– 1,19X4+ 2,44X5– 0,02X6+ 2,65X7 – 0,06X8+ 6,68 \quad (6)$$

Where X_1 − cerebral edema (yes- 1; no- 2);

X_2 − log LII on the 3rd day;

X_3 − concentration of potassium ions in the blood on the 3rd day (mmol/l);

X_4 − cardiovascular diseases (yes- 1; no- 2);

X_5 − log level of urea in the blood (mmol/l);

X_6 – patient age;

X_7 − log absolute lymphocyte count (X_7×109/l) on day 3;

X_8 − leukocyte level on day 1 (X_8×109/l).

2. Statistical decision rule: if CLDF<0, the prognosis for the patient is considered favorable; if CLDF>0, it is unfavorable.

Below is the methodology for calculating the prognosis of immediate outcomes using the example of a patient from the retrospective dataset: patient G., 49, was delivered to the clinic on 22.02.2016 by an ambulance team. Domestic injury. The patient was diagnosed with: Open craniocerebral injury. Severe brain contusion with the formation of a contusion-hemorrhagic focus in the left temporo-occipital region. Subarachnoid hemorrhage. Basal skull fracture in the anterior cranial fossa. Fracture of the maxilla according to the upper, middle and lower types on both sides. Closed chest injury. Fracture of the VIII-X ribs on the right. Right-sided pneumothorax.

According to the medical history, the patient died on 08.03.2016, on the 15th day after the injury. Table 37 presents the methodology for calculating the prognosis of immediate outcomes in patient G. using the presented model. As can be seen from the table, the value of CLDF> 0. According to the statistical decision rule, the prognosis of the injury outcome is assessed as unfavorable.

Table 37. Calculation of the prognosis of the immediate outcomes of the midface combined trauma (patient G.)

Sign	Value	Coefficients	Score
Cerebral edema	1	-2,32	-2,32
log LII (on Day 3)	0,9	4,87	4,38
K+(on Day 3)	4,1	-1,01	-4,14
CVD	2	-1,19	-2,38
log BU (on Day 3)	0,77	2,44	1,88
Age	49	-0,02	-0,98
log Lym (on Day 3)	-0,14	2,65	-0,37
WBC (on Day 1)	23,5	-0,06	-1,41
Constant	-	-	6,68
Sum	-	-	1,34

As in the first variant of the CLDF, the highest factor load among the signs included in the second variant of the CLDF was found in the sign of CE (Table 36). These data indicate a serious impact that the development of such a complication has on the immediate outcomes of a concomitant midface trauma. The probability of a fatal outcome increases with an increase in the values of signs of age, LII (Day 3) and BU (Day 3), as well as with a decrease in the values of signs of WBC (Day 1), Lym, and K + (Day 3, respectively). If the patients have a history of CVD, the probability of a fatal outcome increases.

CHAPTER 5.
TREATMENT OF PATIENTS WITH CONCOMITANT MIDFACE TRAUMA

5.1. Tactic of Multi-Stage Surgical Treatment and the algorithm for treating patients with combined midface trauma

The treatment of patients with severe and extremely severe combined injuries of the first and second groups of observed patients was carried out using the MST tactic, taking into account the severity and level of compensation of the physiological status of the patients according to the developed algorithm. Below we present the main stages of the MST tactic for patients with combined midface trauma:

The MST tactic in patients with concomitant midface trauma includes the following stages:

Stage I of MST corresponds to the first period of TD - the period of acute impairment of vital functions. This period lasts up to 12 hours from the moment the patient is admitted to hospital. The goal of the first stage is to eliminate the life-threatening consequences of trauma, including the elimination of asphyxia and performing tracheostomy, while creating physiological statuss for intensive therapy, stopping bleeding, eliminating compression of the brain; temporary fixation of fragments by orthopaedic method in order to stop bleeding, and performing elements of primary soft tissue plasty. These measures are carried out in the anti-shock operating room synchronously with similar actions of specialists of other profiles [11, 24, 25, 56, 58, 88, 90].

Primary soft tissue plasty is performed when there are extensive penetrating wounds with soft tissue defects; when there are wounds with soft tissue defects in the eyelids, nose, auricles, and lips; when parts and organs of the maxillofacial region, such as the nose, lips, and auricles, are torn off [88].

Stage II of MST corresponds to Periods 2 and 3 of TD and lasts from 2 to 10 days. At the second stage, intensive therapy is carried out to achieve temporary

stabilisation of the physiological status of the patient; measures are aimed at preventing and treating infectious complications. The second stage can be divided into 2 parts: 1-3 days - long-term ventilator therapy, infusion-transfusion therapy (transfusion of erythroconcentrate, freshly frozen plasma, plasma-substituting solutions) and de-escalation antibiotics therapy (ABT); 4-10 days - targeted ABT taking into account the culturing results, and minimally invasive operations (rehabilitation of potential sources of infectious complications). In certain cases, staged fixation of fragments is carried out using minimally invasive extra-focal osteosynthesis [70, 71]. At this stage, an exhaustive diagnosis of damaged structures using CT is also carried out. A component of complex treatment is restoration of damaged structures to functional capacity, including the insertion of a feeding tube through a stoma or the placement of a gastrostomy [11, 24, 25, 51, 56, 58, 90].

Stage III of MST is reconstructive and restorative and corresponds to the 4th TD period. The third stage can be started after the final stabilisation of the physiological status of the patient. Surgical interventions are performed in full and extra-focal osteosynthesis is replaced by intraosseous osteosynthesis in order to achieve complete stabilisation of the fracture, eliminate aesthetic defects, and restore the bite [11, 24, 56, 58, 90].

To assess the severity and level of compensation of the physiological status of the patients, a technique used at the clinical facilities of the Department of Maxillofacial Surgery and Surgical Dentistry of St Petersburg University was used, which consists in assessing the following seven signs: data on inotropic support for the patient, systolic blood pressure, heart rate, haematocrit level, haemoglobin level, concentration of blood erythrocytes, the severity of the physiological status on the Military Field Surgery Scale - Selective Physiological status Assessment (MFS-SC). The MFS - SC scale was developed by the Doctor of Medical Sciences, Professor E.K. Gumanenko and candidate of medical sciences V.V. Suvorov at the Kirov Military Medical Academy in 2005 [20, 26, 75, 89]. The quantitative limits of these signs for each level of compensation of the physiological status are presented in Table 38.

Table 38. Methodology for assessing the level of compensation for the physiological status of patients with concomitant craniofacial trauma

Sign	Level of compensation of the physiological status of the patients		
	Decompensation	Subcompensation	Compensation
Inotropic support	Given	Not given	Not given
Systolic Blood Pressure (mmHg)	≤ 80	81-100	>100
HR	<60 or >140	91-140	60-90
Haematocrit (%)	20-25	26-31	>31
Haemoglobin (g/l)	60-84	85-99	>99
Red blood cells ($^{10-12}$/l)	<2.5	2,6-2,9	>2.9
MFS - SC, score	70-98	50-69	<50

When using this method, the general decompensation conditions are checked first. If there is at least one decompensation condition, the general condition is assessed as decompensated. In the absence of decompensation conditions, the subcompensation conditions are checked. In the absence of decompensation and subcompensation conditions, the overall condition is assessed as compensated.

In a decompensated patient's general condition, the extent of necessary and tolerable surgical care corresponds to Stage I of MST; in a subcompensated condition - to Stage II; and in a compensated condition - to Stage III. Thus, reconstructive operations are not always postponed for the fourth period of TD (after 10 days), and their timing is determined directly taking into account the severity of the general condition of the patient.

The presented algorithm for treating patients with combined midface trauma (Figure 14) was developed based on the results of the clinical and biometric analysis conducted in this study, as well as the main provisions of the MST tactic.

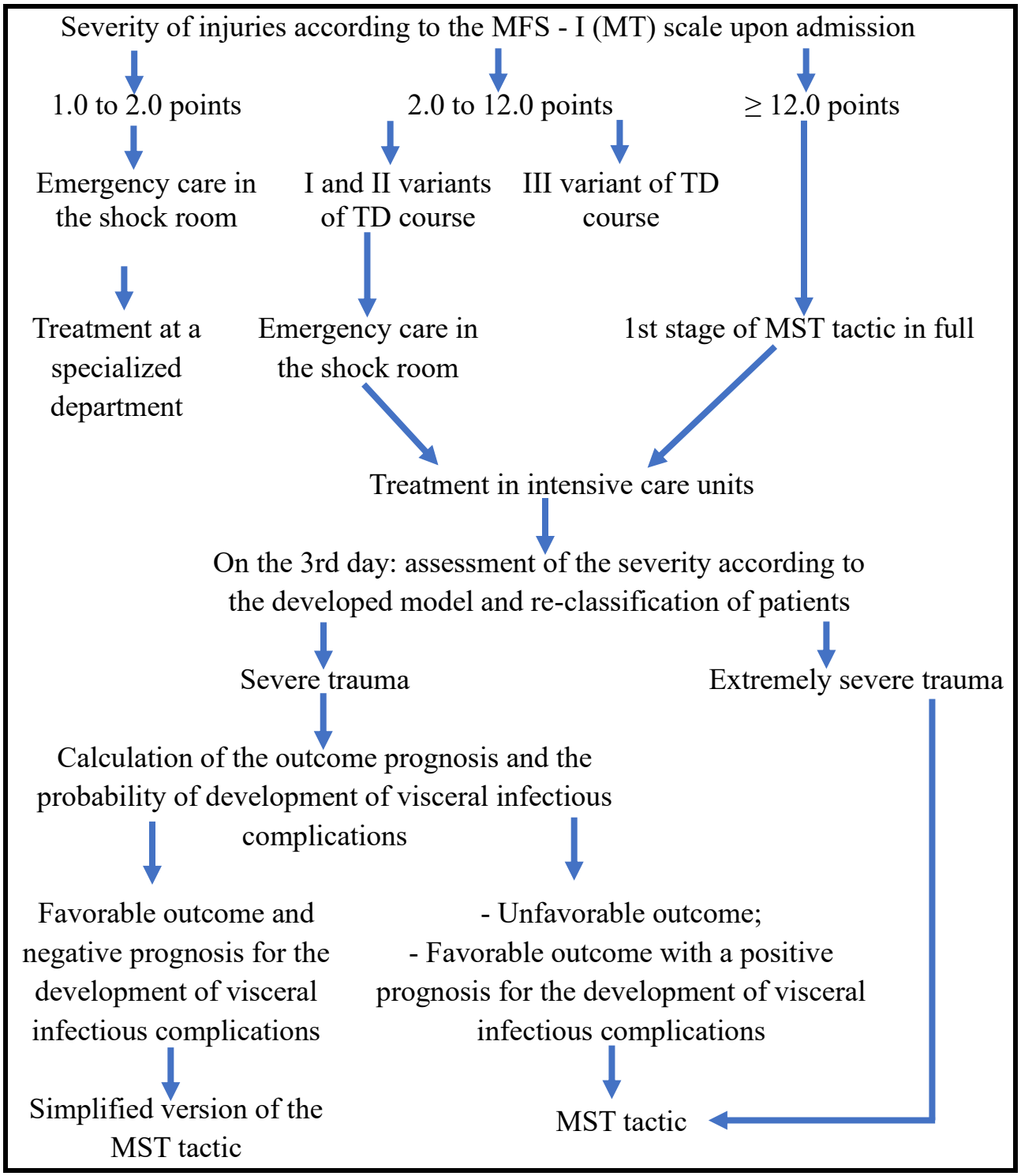


Figure 14. The algorithm for treating patients with combined midface trauma.

The MST tactic of patients with combined midface trauma, as already described, includes a whole range of surgical interventions implemented from the moment of admission of the patient to the hospital and completed by the reconstructive and restorative stage. Depending on the severity of the patient physiological status, the

severity of injuries, the nature and severity of the course of the traumatic disease, the list of surgical interventions carried out within the framework of the MST tactic may differ. In the practice of a maxillofacial surgeon, difficulties often arise in making a decision regarding the need for a tracheostomy as a stage of preparation for long-term mechanical ventilation, gastrostomy in order to achieve functional rest in case of jaw fractures and staged fixation of fractures of the midface bones, using the method of extrafocal osteosynthesis. In the description of the algorithm for treating patients developed by us, we will use the term "simplified version" to denote a version of the MST tactic, in which these surgical interventions are not carried out.

When the patient is admitted to the hospital, the severity of the injury is assessed using the MFS - I (MT) scale:

- Injury severity from 1.0 to 2.0 points. Patients of this category are treated according to the simplified version of MST tactic. The patient is provided with emergency care in the shock room, and after the stabilization of his physiological status, he is transferred to a specialized department to continue treatment.

- Injury severity from 2.0 to 12.0 points. In the case of a decompensated version of the course of traumatic disease (option III), when life-threatening complications occur in its first period, the first stage of the MST tactic is carried out in full. In other cases, the first stage of the MST tactic is carried out according to a simplified version.

- Injury severity ≥ 12 points. The first stage of the MST tactic is carried out in full for patients of this category.

On the 3rd day of hospital stay, the severity of trauma is assessed for the patients in the intensive care units using the developed model for assessing the severity of combined midface trauma based on objective combined determinants. In the case of extremely severe trauma, the patients are treated according to the MST tactic. In the case of severe trauma, the prognosis of the immediate outcomes and the probability of developing visceral infectious complications are calculated. If the predicted immediate outcome is favorable and the prognosis of the probability of developing visceral infectious complications is negative, the patient is treated according to a simplified version of the MST tactic. In the case of an unfavorable prognosis of immediate

outcomes, as well as a favorable prognosis of immediate outcomes and a positive prognosis of the probability of developing visceral infectious complications, MST tactic are implemented in full.

5.2. Treatment of Patients with Severe Concomitant Midface Trauma

5.2.1. Clinical Characteristics of Patients with Severe Concomitant Midface Trauma

When creating the study groups to solve the third task of the study, the author was guided by the classification of the severity of damage on the MFS - I (MT), according to which injuries estimated at 1.0 to 12 points are attributed to severe injuries; and at ≥ 12 points - to extremely severe. 48 patients were included in a group of patients with severe concomitant midface trauma. They were divided into two groups: the first group - included 27 patients — it is the group of the author's own observations. This group will be conventionally called the first group of observed patients; the second group included data on 21 patients collected by the retrospective method. The second group will be conventionally called the first retrospective group.

In addition to injuries to the midface zone, all the patients, both in the group of observed patients and the retrospective group, were diagnosed with injuries to other anatomical areas. Injuries in the head and, including the cerebral part of the skull, were diagnosed in 100% of the patients. Open TBI was diagnosed in 25 (92.6%) patients of the first group of observed patients and in 11 (52.4%) patients of the first retrospective group; closed TBI - in 2 (7.4%) and 10 (47.6%) patients, respectively. The second most frequent injury is to the chest area; the third most frequent is to the extremities. The distribution of injuries by anatomical areas in the patients of the first group of observed patients and the first retrospective group is presented in Table 39.

Table 39. Distribution of injuries by anatomical areas in patients with severe concomitant midface trauma

Anatomical area	Group and number of patients			
	1st retrospective group n=21		1st group of observed patients n=27	
	absolute number	%	absolute number	%
Head	21	100	27	100
Neck	1	4.8	0	0
Chest	9	42.9	5	18.5
Stomach	3	14.3	0	0
Pelvis	2	9.5	0	0
Spine	3	14.3	2	7.4
Limbs	7	33.3	6	22.2

In all the patients of the first group of observed patients, as well as in 12 (57.1%) patients of the first retrospective group, most severe injuries were localised in the head area; in 4 (19%) patients of the first retrospective group - in the chest area; in 3 (14.3%) - in the extremeties; in 1 (4.8%) - in the spine and abdomen. In addition to midface injuries, the patients of the first group of observed patients were diagnosed with injuries, on average, in 1.3 anatomical areas; of the first retrospective group - in 1.9.

On admission to the clinic, all the patients (n=48) were treated in the shock ward of the emergency department and, later, in the rescusitation and intensive care units. The differences in the severity of injuries in the groups on the ISS scale and the MFS - I (MT) scale are statistically insignificant (Table 40).

Table 40. Severity of injuries in the first group of observed patients and the first retrospective group

Severity of injury, score; median [min.; max.]	Group and number of patients		Mann-Whitney p-level
	1st retrospective group n=21	1st group of observed patients n=27	
MFS - I (MT)	2,75[1,2; 10,55]	2,65 [2,1; 7,65]	0.547
ISS	21 [8; 29]	21 [9; 29]	0.716

The frequency of damage to the bone structures of the midface in the patients of the first group of observed patients is higher than in the patients of the first retrospective group, and midface soft tissue injuries were diagnosed more often in the first retrospective group. The first place among the fractures of the midface bones in both groups is occupied by fractures of the eye socket walls, and the second - by fractures of the upper jaw. On average, the patients of the first group of observed patients were diagnosed with fractures of 2.2 midface bones; the patients of the first retrospective group - of 1.8. The distribution of midface injuries by groups is presented in Table 41.

Table 41. Distribution of midface injuries in patients of both groups

Anatomical location	Group and number of patients			
	1st retrospective group n=21		1st group of observed patients n=27	
	absolute number	%	absolute number	%
Upper jaw	8	38.1	15	55.6
Eye socket	12	57.1	19	70.4
Zygomatic bone	7	33.3	11	40.7
Nose bones	6	28.6	14	51.9
Soft tissues	16	76.2	10	37

In the majority of observed patients of the first group (n=26 (96.3%)) the first variant of the course of traumatic disease was observed; the second variant was observed only in one patient (3.7%). In the first retrospective group, the first variant of the course of traumatic disease was detected in 66.7% (n=14) of patients; the second variant - in 23.8% (n=5). The third variant of the course of traumatic disease was observed only in two patients (9.5%) of the first retrospective group, and in the first group of own observations it was not detected. The distribution of patients of both groups, depending on the course of the traumatic disease, as well as the immediate outcomes of the combined injury in each variant are presented in Table 42.

Table 42. Distribution of patients according to the course of the traumatic disease and the immediate outcome of the combined injury

Indicator		Group and number of patients					
		1st retrospective group n=21			1st group of observed patients n=27		
		I	II	III	I	II	III
Absolute number of patients (%)		14; (66,7%)	5; (23,8%)	2; (9,5%)	26; (96,3%)	1; (3,7%)	0; (0%)
Severity of injury (score) - median [min; max.]	MFS - I (MT)	2,75 [1,2; 10,55]			2,6 [2,1; 8,55]		-
	ISS	21 [8; 29]			21 [9; 29]		-
Survived, absolute number (%)		14; (100%)	3; (60%)	0; (0%)	26; (100%)	1; (100%)	-
Died, absolute number (%)		0; (0%)	2; (40%)	2; (100%)	0; (0%)	0; (0%)	-

5.2.2. Results of Treatment of Patients with Severe Concomitant Midface Trauma

According to the concept of multi-stage surgical treatment (Damage Control Orthopaedics), decisions on the timing and scope of necessary and permissible surgical care for the patient are made taking into account the overall physiological status severity, as well as the nature (variant) of the course of the traumatic disease. Only if this physiological status is met, the decisions made can be considered justified.

We assessed the level of compensation of the physiological status of the observed patients of the first group (n=27) on Days 1, 3, 7, and 14 of inpatient treatment. The results are presented in Table 43. As can be seen from the table, despite the presence of severe injuries, the physiological status of almost half of the patients (55.6%) was assessed as compensated. The proportion of patients with compensated physiological status increased on Day 3, and by Day 7 was 100%, which indicates complete stabilisation of their physiological status.

Table 43. The level of compensation of the physiological status of observed patients in the first group in dynamics

Day	Number of patients		Level of compensation of the physiological status					
			Compensation		Subcompensation		Decompensation	
	absolute number	%	absolute number	%	absolute number	%	absolute number	%
1	27	100	15	55.6	10	37	2	7.4
3	27	100	22	81.5	5	18.5	0	0
7	26	96.3	26	100	0	0	0	0
14	10	37	10	100	0	0	0	0

Below is a clinical example of the implementation of a multistage surgical treatment tactic in a patient with severe concomitant midface trauma:

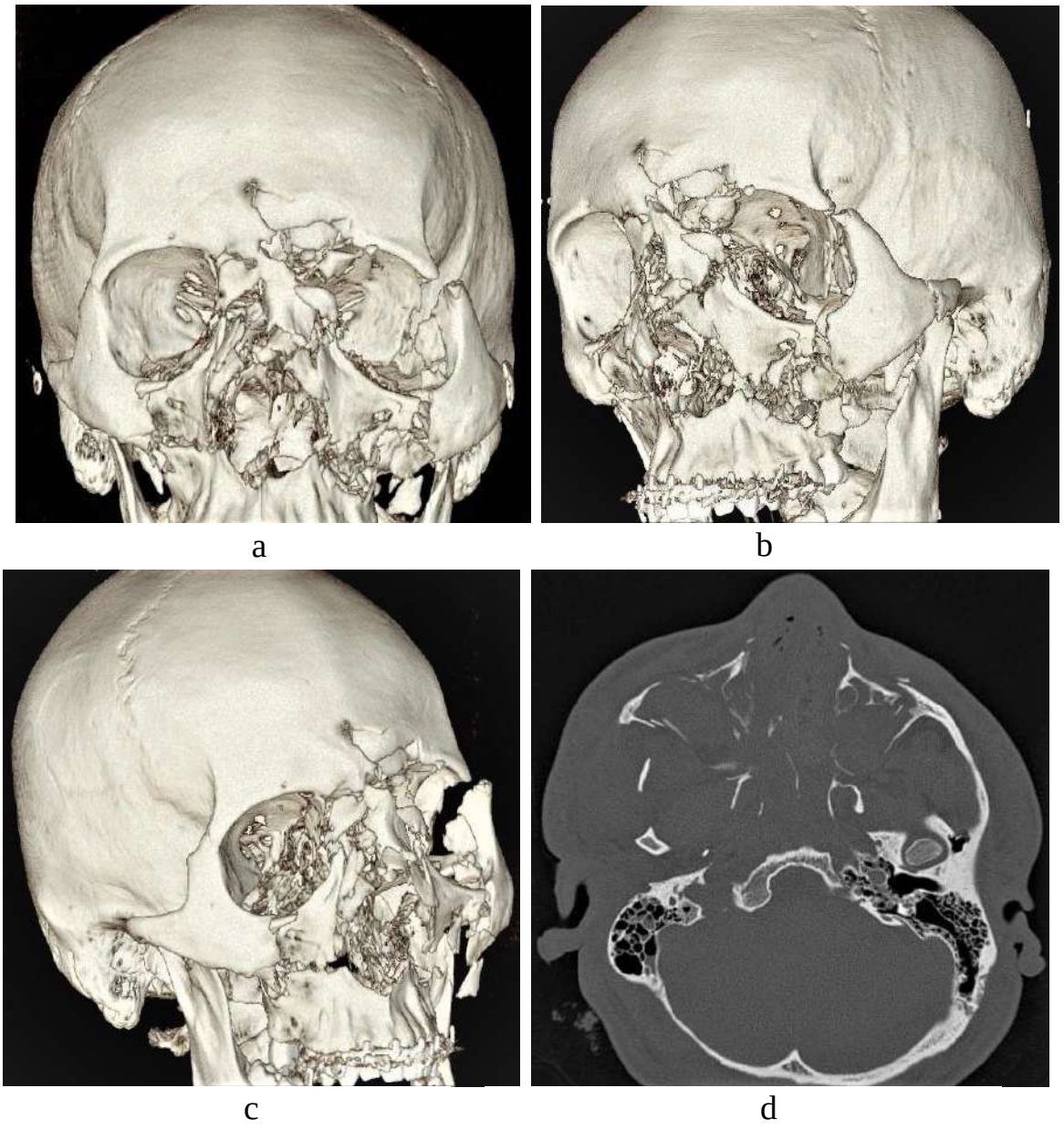
Clinical example No. 1:

Patient B., 26 years old, was brought to the clinic on 08 March 2019 by an ambulance team. The injury occurred as a result of an attack with the use of physical force. After examination, the patient was diagnosed with an open craniocerebral injury. Moderate brain contusion. Fracture of the base of the skull in the anterior cranial fossa and the middle cranial fossa on both sides. Fracture of the upper jaw of the upper, middle, and lower types on both sides. Fracture of the ethmoid bone. Fracture of the supraorbital rim on the left. Bilateral Type 3 Nasoorbitoethmoidal Complex Fracture with Left Medial Canthal Ligament Avulsion. Fracture of the walls of both eye sockets. Fracture of the bones of the nose. Polyposis of the Sinuses. Bilateral zygomatic arch fracture. Lacerations on the left shoulder and right thigh. Contusions of the frontal and occipital regions. Stab-cut wound of the right chest wall.

The severity of injuries on the MFS - I (MT) scale was estimated at 2.65 points (severe), on the ISS scale - at 21 points. Upon admission to the clinic, the level of consciousness on the Glasgow Coma Scale was estimated at 12 points (severe concussion). In Figure 15, sections from the CT scan of the skull of the patient are presented, taken on the third day after the injury.

The patient, upon admission to the clinic, received immediate assistance in the shock room, synchronously with the actions of specialists from other disciplines.

Emergency aid was provided, including the cessation of nasal bleeding, relief of asphyxia, and mandibular splinting performed by maxillofacial surgeons (Dr. K.G.M. and Dr. S.E.V.)



a b c d

Figure 15. CT scan of the skull of the injured patient B., 26 years old, on the 3rd day after the injury: a) anterior view; b) left lateral view; c) right lateral view; d) coronal projection.

The patient was transferred to the intensive care unit (ICU). The time of the patient's stay in the ICU was 81 hours.

In the intensive care unit, the patient received the following treatments: mechanical ventilation therapy, transfusion of fresh frozen plasma, infusion therapy, and antibiotic therapy. ‘On the third day, a computed tomography scan of the damaged structures was performed, along with sanitation of the maxillary sinuses.’ The trauma on the 3rd day was assessed as severe, with a favorable prognosis for the outcome and a negative prognosis for the development of visceral infectious complications. Tracheostomy, gastrostomy and staged fixation of midface bone fractures using extrafocal osteosynthesis methods were not performed.

On the sixth day of inpatient treatment and following the final stabilisation of the patient's overall physiological status, the third stage of surgical treatment was performed - reconstructive-restorative. The extent of the surgical interventions performed is as follows: reconstruction of the cranial vault defect. Reduction and osteosynthesis of the left zygomatic bone. Reduction and osteosynthesis of the upper jaw using the lower approach. Reconstruction of the lower wall of the right orbit. The duration of the operation was 5 hours (surgeons: Dr. S.E.L., Dr. K.G.M., Dr. A.K.A.). Figure 16 shows the sections from the CT scan of the skull of the patient after the reconstructive-restorative surgeries were performed.

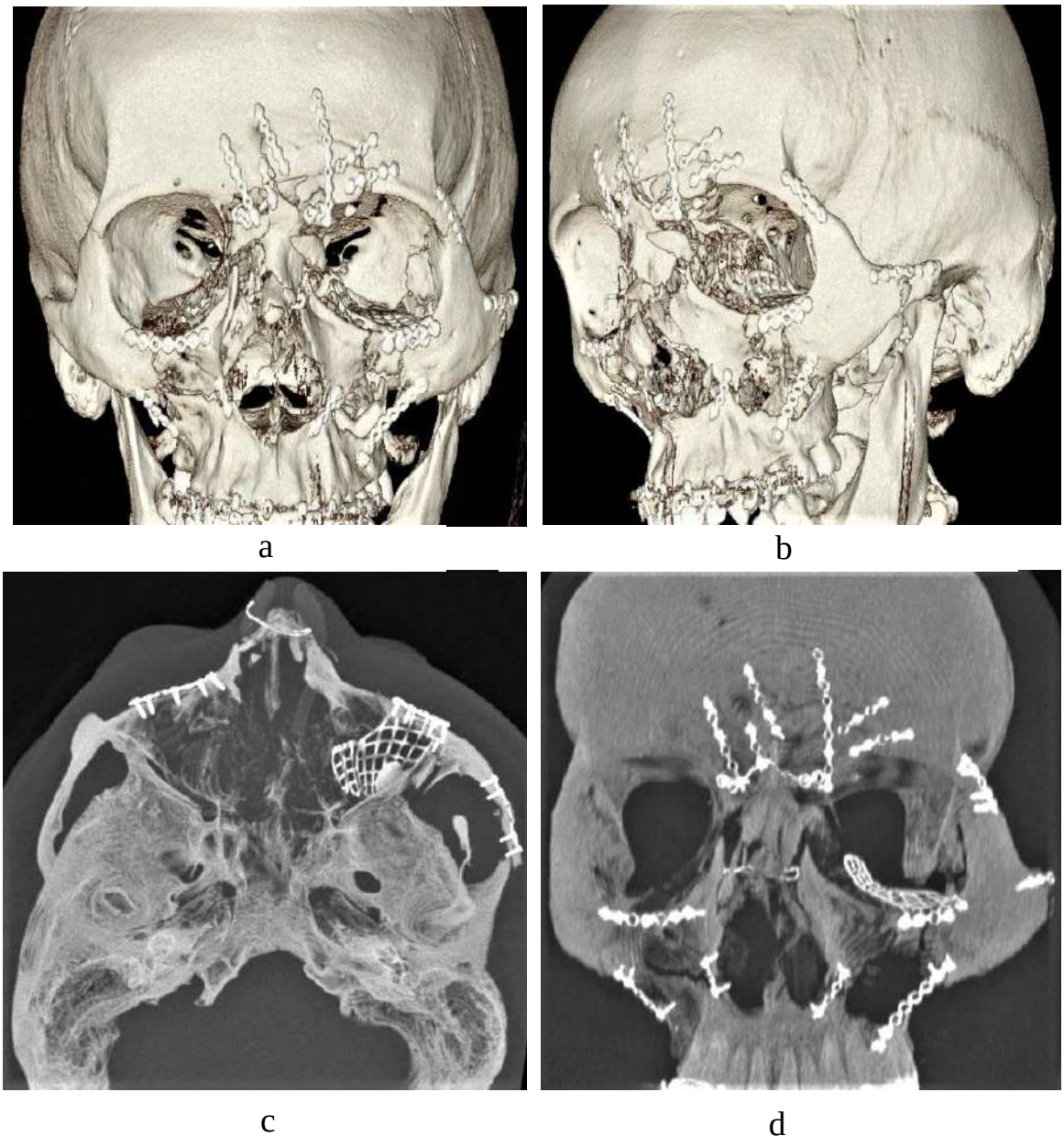


Figure 16. CT scan of the skull of the injured patient B., 26 years old, after the reconstructive-restorative surgeries: a) anterior view; b) left lateral view; c) coronal projection; d) axial projection.

During the postoperative period, the patient experienced an infectious complication (poly-sinusitis). The patient was discharged from the clinic in a satisfactory physiological status. The duration of hospital stay was 41 days.

The main method of fixation for fractures of the craniofacial complex in the first group of observed patients was a combined approach (intraosseous metal osteosynthesis and orthopaedic fixation methods) It was applied in 14 patients (51.9%).

In isolated form, intraosseous metal osteosynthesis was performed in 7 patients (25.9%), while the orthopaedic method was used in 3 patients (11.1%). Due to the absence of functional and aesthetic impairments, fixation of the craniofacial fractures was not performed in 3 patients (11.1%).

Complicated courses of traumatic disease were observed almost three times more frequently in the retrospective group of patients compared to the observed group. Infectious complications prevailed over non-infectious ones in the patients of both groups. The frequency of the most commonly encountered infectious and non-infectious complications in patients with severe concomitant midface trauma is presented in Table 44.

Table 44. The frequency of complications in patients with severe concomitant midface trauma

Indicator	Group and number of patients			
	1st retrospective group, n=21		1st group of observed patients n=27	
	absolute number	%	absolute number	%
Complicated course of TD	10	47.6	4	14.8
Infectious complications	8	38.1	3	11.1
Non-infectious complications	2	9.5	1	3.7
Cerebral oedema	2	9.5	0	0
Pneumonia	6	28.6	0	0
Tracheobronchitis, endobronchitis	1	4.8	0	0
Meningitis, meningoencephalitis	0	0	0	0
Organ and multiple organ failure	3	14.3	0	0
Sepsis, severe sepsis, septic shock	5	23.8	0	0
Sinusitis, polysinusitis	1	4.8	3	11.1
Cystopyelonephritis	0	0	0	0
Thrombosis, thromboembolism	1	4.8	0	0
Perimaxillary abscesses and phlegmons	0	0	3	11.1
Other complications	6	28.6	1	3.7

Severe and life-threatening complications, such as cerebral oedema, organ or multiple organ failure, pulmonary embolism, and purulent-septic complications were

observed in 7 (33.3%) patients from the first retrospective group. In the observed group of patients, no life-threatening complications were identified. These data suggest a more severe course of traumatic disease in patients of the first retrospective group.

The average duration of treatment of the observed patients of the first group in the ICU wards was 3.1 ± 1 days; of the patients of the first retrospective group - 4.9 ± 3.5 days. The average duration of hospitalisation in the observed patients of the first group was 14.2± 7.9 days; in the patients of the first retrospective group - 18.3± 8 days.

The immediate outcome of severe concomitant midface trauma turned out to be favourable in all the observed patients of the first group; in the first retrospective group - in 17 (81%) of the patients. An unfavourable outcome of the injury was observed in 4 (19%) patients of the first retrospective group.

5.3. Treatment of Patients with Extremely Severe Concomitant Midface Trauma

5.3.1. Clinical Characteristics of Patients with Extremely Severe Concomitant Midface Trauma

The cohort of patients with extremely severe concomitant midface trauma includes 57 patients. Two groups were formed from this cohort: the first group includes 21 patients — this is the group personally observed by the author. This group will be conventionally called the second group of observed patients; the second group included data on 36 patients collected by the retrospective method. The second group will be conventionally called the second retrospective group.

In addition to midface injuries, all the patients, both the second observed group and the second retrospective group, were diagnosed with injuries to one or several other anatomical areas. Injuries in the head region are diagnosed more frequently than in other anatomical areas. TBI with severe brain contusion was detected in all patients (n=57). In the observed group of patients, injuries in the limb region are the second most frequent, followed by injuries in the chest region in third place. In the retrospective group of patients, injuries in the chest region were identified more

frequently than injuries in the limb region. The distribution of injuries by anatomical areas in the patients of the second observed group and the second retrospective group is presented in Table 45.

Table 45. Distribution of injuries by anatomical areas in patients with extremely severe concomitant midface trauma

Anatomical area	Group and number of patients			
	2nd retrospective group, n=36		2nd observed group, n=21	
	absolute number	%	absolute number	%
Head	36	100	21	100
Neck	0	0	1	4.8
Chest	17	47.2	4	19
Stomach	4	11.1	1	4.8
Pelvis	2	5.6	1	4.8
Spine	3	8.3	1	4.8
Limbs	13	36.1	6	28.6

In all the patients of the second observed group of their own observations and the second retrospective group (n=57), injuries leading in severity were localised in the head area. Open TBI was diagnosed in 14 (66.7%) patients of the second observed group and in 21 (58.3%) patients of the second retrospective group; closed TBI - in 7 (33.3%) and 15 (41.7%) patients, respectively. The severity of TBI on the MFS - I (MT) scale in all cases was assessed as extremely severe (≥12 points). In addition to midface injuries, the patients of the second observed group of were diagnosed with injuries, on average, in 1.3 anatomical areas; of the first retrospective group - in 1.9. On admission to the clinic, all the patients (n=57) were treated in the shock ward of the emergency department and, later, in the rescusitation and intensive care units.

Table 46 shows the severity of injuries in the patients of the second observed group and the second retrospective group according to the MFS-I (MT) and the ISS scales. The differences in the severity of injuries by groups are not statistically significant ($p > 0.05$).

Table 46. Severity of injuries in the second observed and the second retrospective groups

Severity of injury, score, median [min; max.]	Group and number of patients		Mann-Whitney p-levels
	2nd retrospective group, n=36	2nd observed group, n=21	
MFS - I (MT)	13,08[12,10; 24,10]	13,70 [12,30; 20,60]	0.170
ISS	30 [26; 50]	30 [29; 45]	0.673

On average, 1.8 fractures of the midface bones were diagnosed in the patients of the second observed group; 1.3 fractures - in the patients of the second retrospective group. The number of injuries to bone structures, as well as soft tissues of the midface area in the patients of the second observed group is higher than in the patients of the second retrospective group. Among the fractures of the midface bones, fractures of the zygomatic bone take the first place in the second observed group, and fractures of the walls of the orbit take the second. In the second retrospective group, fractures of the orbit walls occupy the first place, and fractures of the upper jaw - the second. The distribution of midface injuries by groups is presented in Table 47.

Table 47. Distribution of midface injuries in patients of both groups

Anatomical location	Group and number of patients			
	2nd retrospective group, n=36		2nd observed group, n=21	
	absolute number	%	absolute number	%
Upper jaw	11	30.6	8	38.1
Eye socket	18	50	11	52.4
Zygomatic bone	9	25	13	61.9
Nose bones	9	25	6	28.6
Soft tissues	21	58.3	14	66.7

In the second observed group of patients, the third course variant of traumatic disease was observed in 47.6% (n=10) of the patients. The second course variant was present in 4 patients (19%), and the first course variant was observed in 7 patients (33.3%). The third course variant of traumatic disease was detected in the patients of the second retrospective group more often than in the patients of the second observed

group, (52.8% of the patients (n= 19)). The second course variant of traumatic disease was observed in 10 (27.8%) patients of the second retrospective group, and the first variant - in 7 (19.4%). The distribution of patients of both groups, depending on the course of the traumatic disease, as well as the immediate outcomes of the combined injury in each variant are presented in Table 48.

Table 48. Distribution of patients according to the course of the traumatic disease and the immediate outcome of the combined injury

Indicator		Group and number of patients					
		2nd retrospective group, n=36			2nd observed group, n=21		
		I	II	III	I	II	III
Number of patients absolute number; (%)		7; (19,4%)	10; (27,8%)	19; (52,8 %)	7; (33,3 %)	4; (19 %)	10; (47,6%)
Severity of injury (score) - median [min; max.]	MFS - I (MT)	13,08 [12,10; 24,10]			13,70 [12,30; 20,60]		
	ISS	30 [26; 50]			30 [29; 45]		
Survived, absolute number (%)		7; (100%)	2; (20%)	0; (0%)	7; (100%)	1; (25%)	1; (10%)
Died, absolute number (%)		0; (0%)	8; (80%)	19; (100%)	0; (0%)	3; (75%)	9; (90%)

5.3.2. Results of Treatment of Patients with Extremely Severe Concomitant Midface Trauma

Dynamic monitoring of the severity of the physiological status of the patients with extremely severe concomitant trauma of the second observed group (n=21) showed that on the first day of inpatient treatment, decompensated physiological status was noted in almost half of the patients (52.4%). On the third day, the number of such patients decreased to 42.9%, and on the seventh day increased to 45%. The proportion of patients with compensated physiological status increased from 0% on day 1 to 30.8% on day 14. These data describe one of the main features of managing patients with

extremely severe trauma - a prolonged lack of stabilisation of the physiological status. This feature emphasises special relevance of the use of the MST tactic, taking into account the dynamics of the course of traumatic disease and changes in the severity of the physiological status of patients of this group. In table 49, one can see the change in the severity of the physiological status of the patients of the second observed group in dynamics.

Table 49. Level of compensation of the physiological status of observed patients in the first group in dynamics

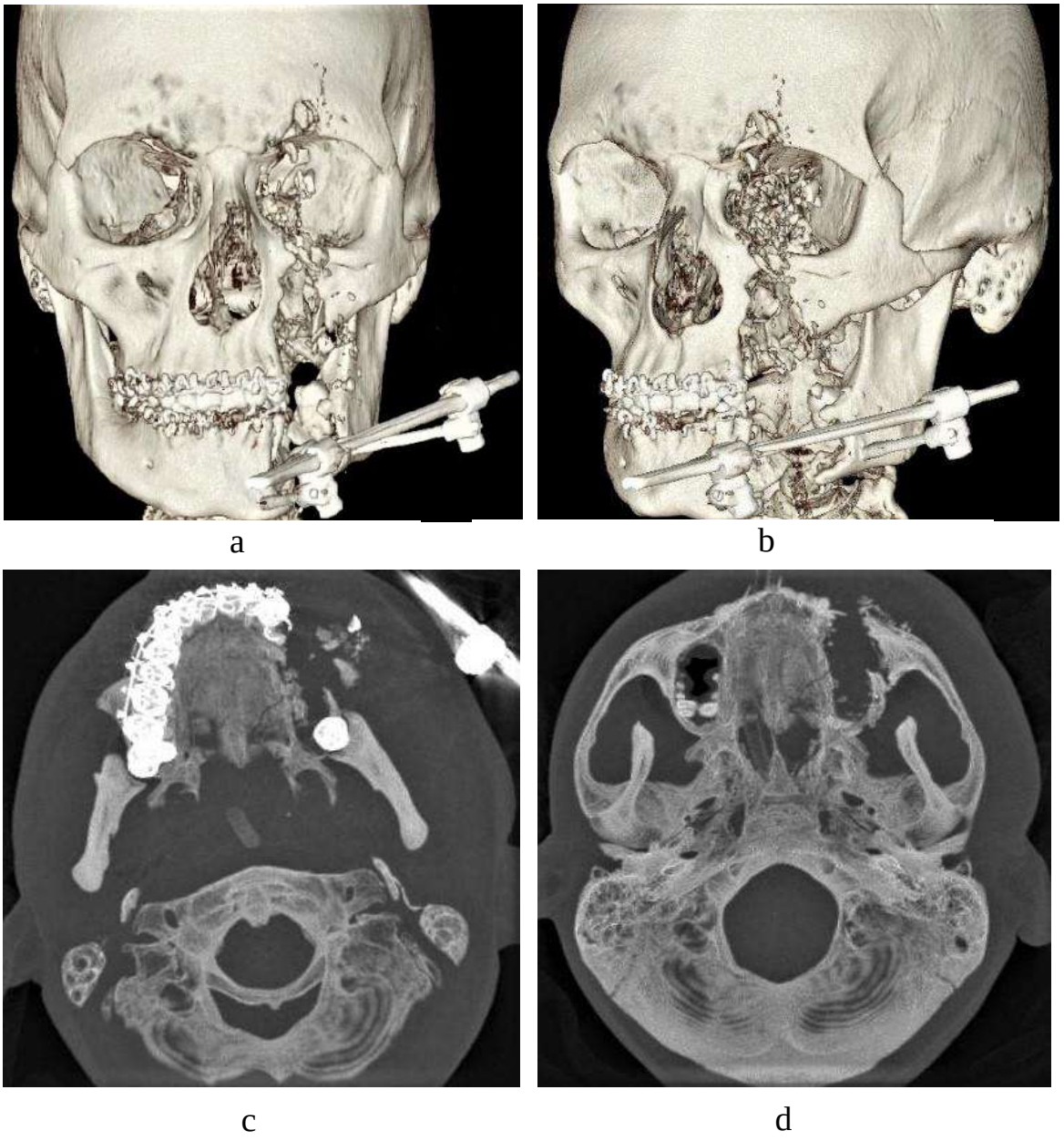
Day	Number of patients		Level of compensation of the physiological status					
			Compensation		Subcompensation		Decompensation	
	absolute number	%	absolute number	%	absolute number	%	absolute number	%
1	21	100	0	0	10	47.6	11	52.4
3	21	100	3	14.3	9	42.9	9	42.9
7	20	95.2	5	25	6	30	9	45
14	13	61.9	4	30.8	6	46.2	3	23.1

Below is a clinical example of the implementation of the multistage surgical treatment tactic in a patient with extremely severe concomitant midface trauma:

Clinical example No. 2:

Patient C., 19 years old, was taken to the clinic by an ambulance team on 13 June 2019 with a gunshot wound from a traumatic weapon. After examination, the patient was diagnosed with a gunshot transcranial and facial penetrating injury involving the oral cavity, left maxillary sinus, left orbital cavity, and frontal sinus. Open traumatic brain injury. Severe brain contusion with the formation of a contusion focus in the left frontal lobe. Comminuted fracture of the mandible in the left body region. Comminuted fracture of the alveolar process of the maxilla on the left side, involving all walls of the left maxillary sinus. Comminuted fracture of the lower, lateral, medial, and upper walls of the left orbit with damage to the muscular apparatus of the left eye. Comminuted fracture of the left zygomatic bone and the walls of the frontal sinus. Multiple gunshot wounds of the oral mucosa, tongue, back and side walls of the pharynx. Foreign bodies

(fragments of bones, teeth) in the soft tissues of the oral cavity, back and side walls of the pharynx. Penetrating wound of the left eyeball. Hemophthalmos on the left. Amaurosis on the left. Bilateral pneumothorax.



a b c d

Figure 17. CT scan of the skull of the injured individual, C., 19 years old, at 3 days after the trauma: a) anterior view; b) left lateral view; c) coronal projection (1); d) coronal projection (2).

The severity of injuries on the MFS - I scale (GW - for gunshot wounds) was estimated at 13.7 points (extremely severe), and on the ISS scale at 30 points. Upon admission to the clinic, the level of consciousness on the Glasgow Coma Scale was

estimated at 5 points (coma). In Figure 17, sections of the cranial CT scan of the injured individual are presented at three days after the trauma.

Upon admission to the clinic, the patient's physiological status was assessed as decompensated. The first stage of MST was implemented, including primary surgical wound management of the maxillofacial area and posterior and lateral pharyngeal walls, sanitation of the left maxillary sinus with foreign body removal. Immobilisation of the upper jaw was achieved using orthopedic methods, and stepwise fixation of the mandibular fracture was performed using an extraoral approach. Tracheostomy was also performed. The procedures were carried out by maxillofacial surgeons (S.E.V., K.G.M., A.K.A., and S.E.L.)

The patient was in the intensive care unit (ICU) for 18 days. The patient underwent mechanical ventilation therapy, fresh frozen plasma transfusion, infusion and antibiotic therapy, as well as a computed tomography of the injured anatomical structures. On 16 June 2019, pleural cavity drainage was performed. On 17 June 2019, a gastrostomy was performed. On 27 June 2019, the patient's overall physiological status was assessed as compensated, and the reconstructive-restorative stage of surgical treatment was carried out, including repositioning and osteosynthesis of the mandible and reconstruction of the orbital walls (performed by maxillofacial surgeons - S.E.L., K.G.M.). Figure 18 shows the sections from the CT scan of the skull of the patient after the reconstructive-restorative surgeries were performed.

The course of the traumatic disease was complicated by the development of endobronchitis and tracheoendobronchitis. The duration of inpatient treatment was 43 days. The patient was discharged from the clinic in a satisfactory physiological status.

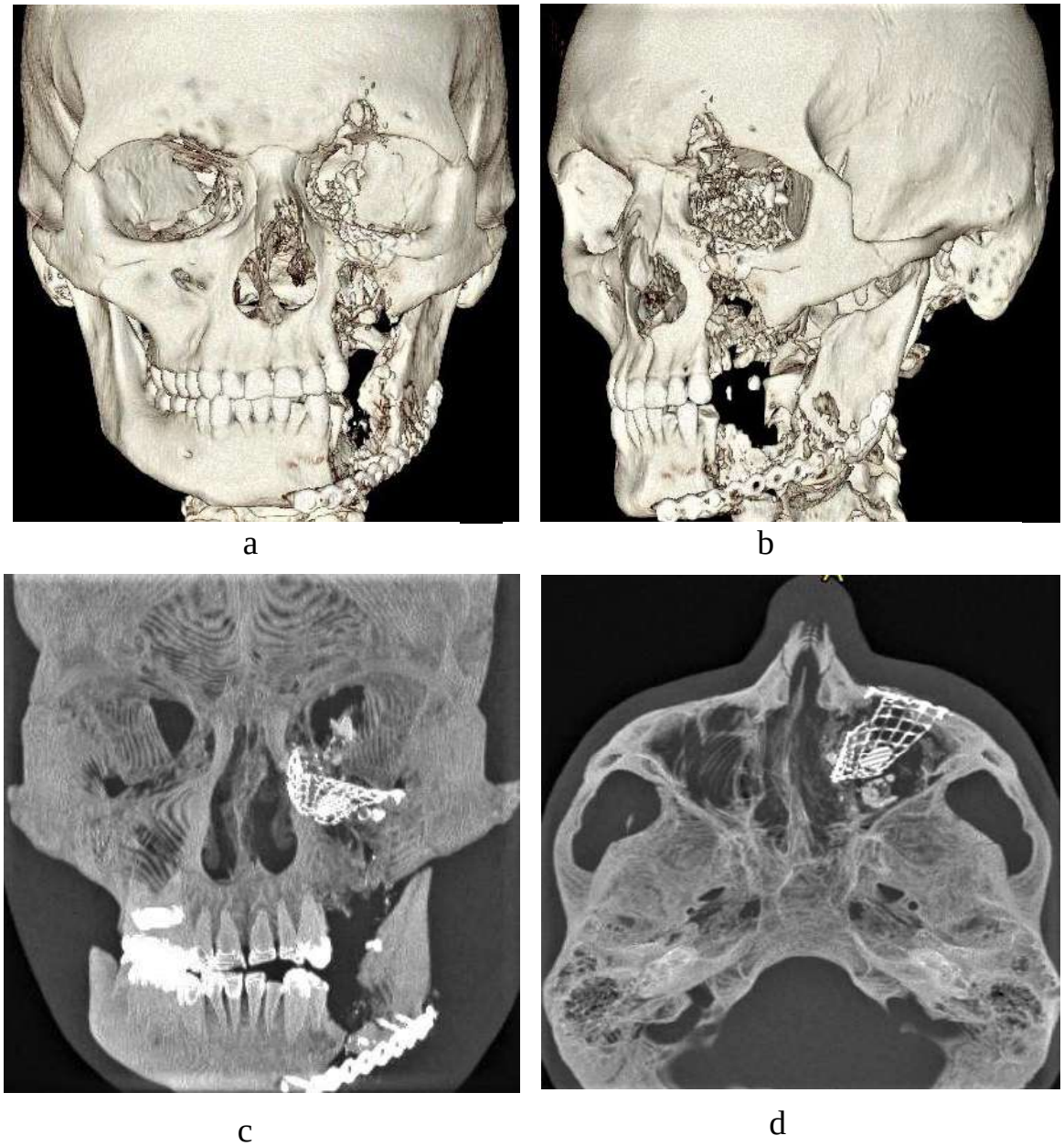


Figure 18. CT scan of the skull of the injured individual C., 19 years old, after the reconstructive-restorative stage of surgical treatment: a) straight view; b) left lateral view; c) axial projection; d) coronal projection.

The fixation of fractures in the midface bones was carried out in only 9 (42.9%) of patients of the second observed group. Orthopaedic methods of fixation of fractures of the midface bones were used in 6 (28.6%) patients; the combined method - in 2 (9.5%) patients; bone metallosteosynthesis - in 1 (4.8%) patient.

The complicated course of traumatic disease in the patients of the second retrospective group was observed in 83.3% of cases; in the patients of the second

observed group - in 71.4% of cases. Most of the patients of both groups with a complicated course of traumatic disease were diagnosed with both infectious and non-infectious complications. The frequency of the most commonly encountered infectious and non-infectious complications in patients with severe concomitant midface trauma is presented in Table 50.

Table 50. The frequency of complications in patients with very severe concomitant midface trauma

Indicator	Group and number of patients			
	2nd retrospective group, n=36		2nd observed group, n=21	
	absolute number	%	absolute number	%
Complicated course of TD	30	83.3	15	71.4
Infectious complications	29	80.6	15	71.4
Non-infectious complications	28	77.8	11	52.4
Cerebral oedema	21	58.3	7	33.3
Pneumonia	28	77.8	14	66.7
Tracheobronchitis, endobronchitis	0	0	5	23.8
Meningitis, meningoencephalitis	10	27.8	5	23.8
Organ and multiple organ failure	15	41.7	3	14.3
Sepsis, severe sepsis, septic shock	16	44.4	9	42.9
Sinusitis, poisinusitis	2	5.6	2	9.5
Cystopyelonephritis	6	16.7	3	14.3
Thrombosis, thromboembolism	1	2.8	1	4.8
Perimaxillary abscesses and phlegmons	2	5.6	1	4.8
Other complications	10	27.8	5	23.8

Life-threatening complications such as cerebral oedema, organ or multiple organ failure, pulmonary embolism, and purulent-septic complications were diagnosed in 29 (80.6%) patients from the second retrospective group and in 13 (61.9%) patients of the second observed group.

The frequency of patients with a fatal outcome of extremely severe concomitant midface trauma in the second observed group was 57.1% (n=12). This indicator was higher in the patients of the second retrospective group and amounted to 75% (n=27).

The comparative characteristics of patients with an unfavourable outcome are presented in Table 51.

Table 51. Comparative characteristics of patients with an unfavourable outcome of extremely severe concomitant midface trauma

Indicator		Subset and number of patients			
		2nd retrospective group, n=36		2nd observed group, n=21	
		absolute number	%	absolute number	%
Number of fatalities		27	75	12	57.1
Time of the lethal outcome, in days	1-3	0	0	0	0
	4-6	3	11.1	1	8.3
	7-9	3	11.1	3	25
	10-12	3	11.1	4	33.3
	13-15	8	29.6	1	8.3
	16-18	1	3.7	0	0
	19-21	2	7.4	0	0
	>21	7	25.9	3	25
Average time of lethal outcome, day M±m		19,9±3,7		18,3±5,4	
Severity of injury, MFS-I (MT), score, median [min.; max.]		12,6 [12,1; 22,1]		14,9 [12,6; 20,6]	
Severity of injury, ISS, score, median [min; max.]		30 [26; 45]		29 [29; 45]	
The level of consciousness on admission by GCS, median [min.; max.]		12 [4; 15]		12 [6; 15]	

The average duration of treatment of the patients of the second observed group in the ICU wards was 12.4 ±3 days; in the patients of the second retrospective group - 12.3 ± 1.2 days. The average duration of inpatient treatment in the patients of the second observed group was 28.3±5.5 days; in the patients of the second retrospective group - 22.6±3.

Thus, the presented algorithm for treating patients with combined midface trauma, based on the key provisions of the tactic of MST tactic taking into account the severity of the trauma, prognosis of the immediate outcomes and prognosis of the risk

of developing visceral infectious complications, is a comprehensive mechanism for making clinical decisions, including regarding the need for tracheostomy as a stage of preparation for long-term mechanical ventilation, gastrostomy to achieve functional rest in case of jaw fractures and staged fixation of fractures of the visceral lymph nodes using the method of extrafocal osteosynthesis. Mathematical models included in this algorithm are a useful tool in determining the indications for these surgical interventions. The introduction of the concept of a "simplified version of the MST tactic" allows us to clarify the principles of implementing the MST tactic in clinical practice. Treatment of patients with severe combined midface trauma according to the presented algorithm led to a decrease in the frequency of infectious complications by 27%, non-infectious complications by 5.8% and a decrease in mortality by 19%; patients with extremely severe combined midface trauma- to a decrease in the frequency of infectious complications by 9.2%, non-infectious complications by 25.4% and a decrease in mortality by 17.9%.

CONCLUSION

The problem of severe concomitant craniofacial trauma is an important task of modern medicine due to its wide prevalence, high probability of infectious complications, and mortality. Damage to the midface area due to its anatomical proximity to the cerebral part of the skull is often combined with TBI. According to M.O. Danilevich, with multiple fractures of the midface bones, patients are diagnosed with moderate and severe TBI in 90.1% of cases [28].

111 patients with severe and extremely severe concomitant midface trauma who were treated at the clinic of the State Medical Institution Alexandrovskaya Hospital of St Petersburg in the period from 2016 to 2020 have been studied. Clinical and laboratory dynamic monitoring of the severity of the physiological status of the patients was carried out. The results of treatment of the patients have been analysed.

The first task of the study was to search for syndrome complexes to assess the severity of the physiological status of patients with concomitant midface trauma in the dynamics of the course of traumatic disease. To address this task, 22 physiological signs were measured, reflecting the degree of dysfunction of vital organs and body systems and fully characterising the physiological status of the patient. Physiological signs were examined at five time points: the 1st, 3rd, 7th, and 14th days from the moment of the injury, as well as on the last day of life of the patients with an unfavourable outcome.

This paper presents a new algorithm for biometric analysis of medical data for patients with severe trauma. The description and justification of this variant are presented below:

The measurement of the studied physiological signs was carried out in two time variants: the first variant is the time of the course of a traumatic disease (traditionally used in medical research). The time count in the first variant begins from the moment of injury, and the time points correspond to the periods of traumatic disease. The second variant of time is the reverse, and since the closest outcome of the trauma is the indicator of group affiliation in the first research task, we refer to the second variant of

time as the time of waiting for the outcome. The values of the studied signs were also collected for the last day of life of patients with a fatal outcome.

Factor analysis (PCA) was performed once with data collected on the last day of life of patients with an unfavourable outcome, and not at each time point. Next, the scores of the already identified factors were measured during the course of the traumatic disease (1st, 3rd, 7th, and 14th days).

The bottom line is that the measurement time of a feature is a key component of any medical study. The individuals who had an unfavorable outcome succumbed at different time intervals from the onset of the trauma. For this reason, time points in the course of the traumatic disease have different clinical significance for different patients. For a patient who passed away on the 4th day, the 3rd day was characterised by significant decompensation of the overall physiological status. For another patient who passed away on the 15th day, the 3rd day has a completely different clinical significance, where the physiological status may be subcompensated. For this reason, when conducting factor analysis at multiple time points during the course of traumatic disease, researchers may encounter the problem of changes in factor structure (variation in the features that form the factors). This, in turn, hinders the interpretation of the factors and prevents the study of dynamic changes in the factors over time, including the ability to conduct comparative analysis of factors among comparison groups. It is also necessary to emphasise the important clinical significance of the last days of life of patients with a fatal outcome, which are characterised by pronounced decompensation and multiple organ failure, for the problem of assessing the severity of the physiological status, which in turn supports our opinion on the feasibility of factor analysis at this time point according to the algorithm described above.

As a result of the factor analysis, three factors were identified, and the total number of signs was halved (from 22 to 11) without significant loss of informativeness. The first factor reflects the nature of morphological ratios of the main cells of the immune system and the severity of general intoxication of the body and infectious complications and includes the following signs: leukocyte intoxication index, neutrophil-lymphocyte ratio, and absolute number of lymphocytes and monocytes. The

second factor reflects the acid-base state and the adequacy of pulmonary ventilation and tissue oxygenation and includes the following signs: blood acidity level, partial pressure of carbon dioxide in arterial blood, blood bicarbonate level, and haemoglobin level. The third factor reflects the functional state of the excretory system and the state of water-electrolyte metabolism and includes the following signs: the concentration of sodium and chlorine ions and the level of blood urea.

After calculating the scores of the selected factors during the course of the traumatic disease (on the 1st, 3rd, 7th, and 14th days), a comparative analysis of the average values of factors in patients with favourable and unfavourable outcomes was carried out, which showed that the division of groups is most clearly based on the first factor.

Further analysis was aimed at studying the signs forming the first factor (LII, NLR, Mono, Lym) separately. Comparative analysis of the signs forming the first factor showed that statistically significant differences in the mean values among the patients with favourable and unfavourable outcomes simultaneously on days 1, 3, 7, and 14 were observed only in the LII sign. These results allow us to conclude that the LII is an independent objective criterion reflecting the severity of the course of the traumatic disease.

Considering the fact that the most common infectious complications in the patients of the retrospective subset were pneumonia and meningitis, a mathematical model was developed to predict the risk of developing visceral infectious complications in patients with the possibility of integrating it into the treatment algorithm. The model was developed using the linear discriminant analysis method. The analysis included the features that form the first factor on the 1st and 3rd days, as well as the severity of damage according to the MFS- I (MT) scale. The developed model includes the following 3 features: the absolute number of lymphocytes and the leukocyte intoxication index on the 3rd day of hospital stay and the severity of damage according to the MFS- I (MT) scale. The classification by the sample was 84.9%.

The next task of the clinical and biometric analysis was to find determinants of trauma severity and develop a mathematical model for classifying patients in intensive

care units on the 3rd day of inpatient treatment. To solve this problem, a comparative analysis of the values of 16 features was performed in two groups of the retrospective subset formed in accordance with the expert assessment of trauma severity. The following signs were included in the analysis: data on the presence of cardiovascular disease (CVD), the occurrence of cerebral edema (CE) and traumatic shock, the severity of traumatic shock (if any), the estimated amount of blood loss, the patient age, the value of the shock index on admission, the severity of injuries according to the MFS- I (MT) scale, heart rate, systolic blood pressure, hemoglobin level, the absolute number of leukocytes, lymphocytes and monocytes, as well as the values of the neutrophil-lymphocyte ratio and the leukocyte intoxication index. The conducted analysis allowed to establish that the differences in the frequencies or medians of the signs of CVD, CE, traumatic shock, estimated amount of blood loss, hemoglobin level, absolute lymphocyte count, neutrophil-lymphocyte ratio, leukocyte intoxication index and the severity of injuries according to the MFS- I (MT) scale in the groups are statistically significant. The development of a model for classifying patients by trauma severity was carried out using linear discriminant analysis. The model included 5 signs: absolute lymphocyte count and hemoglobin level on the 3rd day of hospitalization, injury severity according to the MFS- I (MT) scale and data on the presence of CVD and CE development. The classification by the sample was 90.4%.

The development of a method for predicting the immediate outcomes of a concomitant midfacde trauma began with the search for a 'critical' time point for making a forecast. To address this task, a method of statistical analysis was applied - factor analysis (PCA) with the inclusion of a set of 22 studied physiological signs, as well as the group affiliation of the patients, depending on the outcome. This analysis was carried out in a separate form with data collected on days 1, 3, 7, and 14.

The obtained results allowed us to conclude that, taking into account the set of physiological signs included in our work, the most optimal time point (critical point) for predicting the immediate outcomes of a concomitant midface trauma is the third day after the injury, where the sign of the group affiliation of the patients 'outcome' was included only the first factor with a factor load of 0.84.

When developing the forecasting method, the method of multivariate statistical analysis - discriminant analysis (DA) was used. The analysis included 26 signs: 22 studied physiological signs, the severity of injuries according to the military field surgery scale - Injury (MT), the age of the patients, data on the development of cerebral oedema in the patients after trauma (CE) and on the history of diseases of the cardiovascular system (CVD).

A method for predicting the immediate outcomes of a concomitant midface trauma has been developed in two variants: with and without the inclusion of signs of blood gas composition. The first variant of the discriminant function (with the inclusion of signs of blood gas composition) included the following 9 signs: age, CE, CVD, LII, blood glucose level, concentration of potassium ions in the blood, INR, pCO2, and pO2. The classification in the sample was 100% (without inversions).

The results of the discriminant analysis showed that the probability of a fatal outcome increases with increasing values of signs of LII, pO2, BG, INR, pCO2 (on day 3, respectively), age, cerebral oedema in patients after trauma (CE), a history of CVD, and a decrease in concentration of potassium ions in the blood (on day 3). At the same time, the highest factor load was observed in the sign of CE.

The second variant of the discriminant function (excluding signs of blood gas composition: SO2, pH, pCO2, HCO3-, pO2) included eight of the following signs: absolute number of leukocytes (on day 1), log LII (on day 3), potassium ion concentration (on day 3), log BU (on day 3), log Lym (on day 3), CE, age, and CVD. The classification in the sample was 98.4% (1 inversion).

The results of the discriminant analysis showed that the probability of a fatal outcome increases with an increase in the values of LII and BU levels (on day 3, respectively), age, cerebral oedema in patients after trauma (CE), a history of CVD, as well as a decrease in the absolute number of leukocytes (on day 1), lymphocytes (on day 3), and the concentration of potassium ions (on day 3). As in the first variant, the highest factor load was observed in the sign of CE.

Taking into account the obtained results of the conducted clinical and biometric analysis, an algorithm for treating patients was formed, based on the key provisions of

the MST tactic taking into account the severity of the injury, the prognosis of the immediate outcomes and the prognosis of the development of visceral infectious complications. Upon admission of the patient to the hospital, the severity of the injuries is assessed using the MFS - I (MT) scale:

- Injury severity from 1.0 to 2.0 points. Patients of this category are treated according to the simplified version of MST tactic. The patient is provided with emergency care in the shock room, and after the stabilization of his physiological status, he is transferred to a specialized department to continue treatment.

- Injury severity from 2.0 to 12.0 points. In the case of a decompensated version of the course of traumatic disease (option III), when life-threatening complications occur in its first period, the first stage of the MST tactic is carried out in full. In other cases, the first stage of the MST tactic is carried out according to a simplified version.

- Injury severity ≥ 12 points. The first stage of the MST tactic is carried out in full for patients of this category.

On the 3rd day of hospital stay, the severity of trauma is assessed for the patients in the intensive care units using the developed model for assessing the severity of combined midface trauma based on objective combined determinants. In the case of extremely severe trauma, the patients are treated according to the MST tactic. In the case of severe trauma, the prognosis of the immediate outcomes and the probability of developing visceral infectious complications are calculated. If the predicted immediate outcome is favorable and the prognosis of the probability of developing visceral infectious complications is negative, the patient is treated according to a simplified version of the MST tactic. In the case of an unfavorable prognosis of immediate outcomes, as well as a favorable prognosis of immediate outcomes and a positive prognosis of the probability of developing visceral infectious complications, MST tactic are implemented in full.

A comparative analysis of the results of treatment of patients with severe concomitant midface injury showed that the complicated course of traumatic disease in the patients of the first retrospective group was almost three times more common than in the patients of the first observed group (47.6% and 14.8%, respectively). Life-

threatening complications (cerebral oedema, organ or multiple organ failure, pulmonary embolism, and purulent-septic complications) were observed in 7 (33.3%) patients from the first retrospective group. In the first observed group of patients, no such complications were detected.

The incidence of infectious complications decreased from 38.1% in the first retrospective group to 11.1% in the first observed group. There was also a decrease in the severity of these complications. Generalised infectious complications prevailed in the patients of the first retrospective group, while local complications prevailed in the first observed group.

The first variant of the course of traumatic disease occurred in 96.3% of patients of the first observed group and in 66.7% of patients of the first retrospective group. The second variant - in 3.7% and 23.8% of patients, respectively. The third variant was observed in 9.5% of patients of the first retrospective group, and in the first observed group it never happened. Overall, the individuals in the first retrospective group exhibited a more severe course of traumatic disease.

The average duration of treatment of patients with severe concomitant midface trauma in ICU wards decreased from 4.9±3.5 days in the first retrospective group to 3.1±1 days in the first observed group ($p=0.02$). The average duration of hospitalisation also decreased from 18.3±8 days in the patients of the first retrospective group to 14.2±7.9 days in the first observed group ($p=0.08$).

An unfavourable outcome of the severe concomitant midface injury was observed in 4 (19%) patients of the first retrospective group. The immediate outcome of the injury turned out to be favourable for all the patients of the first observed group.

A comparative analysis of the results of treatment of patients with extremely severe concomitant midface trauma showed that the number of patients with a complicated course of traumatic disease decreased from 83.3% in the second retrospective group to 71.4% in the first observed group. The first variant of the course of traumatic disease was observed in 33.3% of patients of the second observed group and in 19.4% of patients of the second retrospective group; the second variant of the course of traumatic disease was observed in 19% and 27.8% of patients, respectively.

The third variant prevailed both in the second observed group (47.6%) and in the second retrospective group (52.8%).

The frequency of life-threatening complications (cerebral oedema, organ or multiple organ failure, pulmonary embolism, and purulent-septic complications) decreased from 80.6% in the second retrospective group to 61.9% in the second observed group.

The number of patients with a fatal outcome of an extremely severe concomitant midface injury decreased from 75% in the second retrospective group to 57.1% in the second observed group. The outcome of an extremely severe concomitant injury with a decompensated course of traumatic disease (variant 3) turned out to be unfavourable in all the patients of the second retrospective group and in 90% of patients of the second observed group. With a subcompensated course of traumatic disease (variant 2), an unfavourable outcome of combined trauma was observed in 80% of patients of the second retrospective group and in 75% of patients of the second observed group. In the compensated variant of traumatic disease course (variant 1), unfavourable outcomes were not observed among the compared groups of patients.

The difference in the average duration of treatment in the ICU wards of patients of the second observed group and the second retrospective group is insignificant. For patients of the second observed group, this indicator was 12.4 ± 3 days; for patients of the second retrospective group - 12.3 ± 1.2 days. The average duration of inpatient treatment in the patients of the second observed group exceeded that of the patients of the second retrospective group and amounted to 28.3±5.5 days and 22.6±3 days, respectively, which is primarily due to the large number of fatal outcomes in the second retrospective group.

FINDINGS

1. The severity of infectious complications in patients with combined midface trauma reflects the severity of the course of traumatic disease as a whole. The dynamics of the average values of the leukocyte intoxication index, neutrophil-lymphocyte ratio, absolute number of lymphocytes and monocytes reflects the nature and severity of the course of traumatic disease. The division of the group of patients with favorable and fatal outcomes according to these signs is most clearly on the 3rd day after the injury. LII is an independent objective criterion reflecting the severity of the course of traumatic disease. A model has been developed for predicting the risk of developing visceral infectious complications with a classification accuracy of 84.9%.

2. The determinants of the severity of the combined midface taruma in patients in the intensive care units on the 3rd day after the injury are: a history of cardiovascular disease, development of cerebral edema or traumatic shock, estimated blood loss, hemoglobin level, absolute lymphocyte count, neutrophil-lymphocyte ratio, leukocyte intoxication index and injury severity according to the MFS-I (MT) scale. A model for assessing the severity of combined midface trauma with a classification accuracy of 90.4% has been developed.

3. Taking into account the set of signs and time points we studied, the 3rd day after the injury is the most optimal for predicting the immediate outcomes of combined midface trauma. A method for predicting the immediate outcomes of combined midface trauma has been developed in two variants: the first variant - with signs of blood gas analysis, where the classification by the sample was 100%; and the second option and - without signs of blood gas composition, where the classification by the sample was 98.4%.

4. In the subset of patients with severe combined midface trauma (MFS-I (MT): from 1 to 12 points), the use of multi-stage surgical treatment tactic taking into account the severity of the injury, the prognosis of the immediate outcomes and the prognosis of the risk of developing visceral infectious complications led to a decrease in the frequency of infectious complications by 27% (from 38.1% to 11.1%), non-

infectious complications - by 5.8% (from 9.5% to 3.7%) and a decrease in mortality by 19% (from 19% to 0%); in the group of patients with extremely severe combined midface trauma (MFS-I (MT) ≥12 points) - to a decrease in the frequency of infectious complications by 9.2% (from 80.6% to 71.4%), non-infectious complications by 25.4% (from 77.8% to 52.4%) and a decrease in mortality by 17.9% (from 75% to 57.1%).

PRACTICAL RECOMMENDATIONS

1. If the severity of injury is from 1.0 to 2.0 points according to the MFS-I(MT) scale, after emergency care in the anti-shock ward and stabilization of the physiological status of the patient, it is recommended to transfer him to a specialized department to continue treatment. The severity of combined midface trauma from 1.0 to 2.0 points according to the MFS-I(MT) scale is marginal between moderate and severe.

2. If the severity of damage is from 2.0 to 12.0 points according to the MFS-I(MT) scale, with a favourable prognosis for immediate outcomes and a negative prognosis for the development of visceral infectious complications, it is recommended to treat patients using the simplified variant of the MST tactic.

3. In case of injury severity from 2.0 to 12.0 points according to the MFS-I(MT) scale, unfavorable prognosis of immediate outcomes and/or positive prognosis of the development of visceral infectious complications, as well as in case of injury severity $\geq$ 12.0 points, it is recommended to implement the MST tactic in full. Patients of this category are recommended to be evacuated to a level I trauma center if they are in other medical institutions.

4. Decisions on the volume of necessary and permissible surgical care for patients with severe and extremely severe combined midface trauma are made exclusively taking into account the level of compensation of the patients physiological status.

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