Book Chapter

Study of Severe Trauma Mechanism of Victims and Prediction of Outcomes of Patients in Road Transport and Other Accidents: Forensic and Clinic Issues

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Abstract

In today's world the high level of injuries caused by anthropogenic risks, traffic accidents, natural disasters, terrorism and other factors, is one of the urgent problems of society and the health system.

In this chapter our aim is to study the features of road transport and other accidents in different countries and to consider the problem and character of road traffic and other injuries such as polytrauma, multiple organ failure, post trauma disorder, etc., which are responsible for the high rate of mortality and disability from transport and other accidents.

We discuss the importance of the problem of mortality from road transport accidents in different countries and analyze it in the cases of some EU countries (Austria, Germany, Czech Republic, Hungary, Poland and Slovakia) and Ukraine. For the more detailed analysis of the forensic and clinical issues of victims killed and injured in road transport accidents the data from Kharkov region (Ukraine) was used. In this research, for the construction of models for survival analysis and prediction of outcomes we have used data on patients with multiple traumas from the V.T. Zaicev Institute of General and Emergency Surgery.

This research applies methods of comparative analysis and various methods of mathematical statistics. For calculations we used such packages as Statistica and Excel. For the comparative analysis in the different countries we used as the fundamental data set the statistical data of Eurostat, materials of reports and articles devoted to problems of injuries and mortality as a result of road and other transportation accidents, an assessment of possible risks and so forth.

The Problems of Road Transport Accidents in the Modern World

According to a report from OECD (OECD, 2013) approximately 1,3 million people are killed each year in the world, most of which are due to road traffic accidents [23]. In 2016 the number of road traffic deaths reached 1,35 million (WHO, 2018) [30]. More than 5 million people were injured in road accidents (OECD/ITF, 2015) and the direct and indirect financial costs of transport accidents are substantial, varying from 1% to 3% of GDP annually [24]. Road traffic injury is now the leading cause of death for children and young adults aged 5-29 years and this is the 8th leading cause of death for people of all ages (WHO, 2018) [30]. The average number of road fatalities per 100 000 inhabitants per year is 18,2 in the world and the figures vary from region to region and from country to country. In Africa and South-East Asia the highest figures are observed, for example the number of road fatalities rate per 100 000 inhabitants was 26,6 in Africa and 20,7 in South-East Asia. In the Eastern

Mediterranean region this indicator was 18 per 100 000 inhabitants, in the Western Pacific the road fatalities rate per 100 000 inhabitants reached 16,9 and in the Americas it was 15,6, while in many countries of the EU it was less than 10. The average OECD mortality rate due to transport accidents was 7 per 100 000 inhabitants in 2013 [23]. There is an essential difference between high-income and low-income countries, thus more than 3 times higher death rates from transport accidents are observed in low-income countries than in high-income countries (WHO, 2018) [30]. As was noted in the report of WHO "Global status report on road safety 2018", "the burden of road traffic deaths is disproportionately high among low- and middle-income countries in relation to the size of their populations and the number of motor vehicles in circulation". For example, the proportion of population in high-income countries is 15%, in middle-income it is 76% and in low-income countries the share of population is 9%. The road traffic deaths were distributed as follows: 80% in middle-income countries, 13% in low-income countries and 7% in high-income countries. The proportion of vehicles was 59% in middle-income countries, 40% in high-income countries and 1% in low-income countries (WHO, 2018). Thus, the 1% of vehicles which were located in low-income countries were implicated in 13% of road traffic deaths [30].

In table A.1 (Appendix) we elaborate data for s sample of mortality rates from road transport accidents for 180 countries in the world for the period 2013-2019 [31] and grouped these countries into quartiles (table A.2, Appendix). We can see that more socially and economically advanced countries, with strict road traffic legal regulations or cultural traditions, better institutional background, etc., were grouped in the first and second quartiles, while emerging or some post-soviet countries and low-income countries were in the third and fourth quartiles.

The issue of the high death and injury rate of the population due to road traffic accidents is one of the most relevant streams of interdisciplinary research, concerning medical and social aspects as well as aspects associated with road transport and public utilities. Death due to road traffic accidents is the primary cause of death in young and middle age [7,12,23,24,30].

According to a number of studies, causes of road accidents include not only human factors (driver error, insufficient driving experience, irresponsible behavior of drivers and pedestrians on the road, driver fatigue, alcohol or drug intoxication, etc.), but also the condition of road transport and public utilities, as well as the enforcement of road safety measures, and the implementation of national programs to regulate all participants of road traffic – this includes their behavior and the control of their vehicles. High- and middle-income countries are characterized by improving emergency care and increasing trauma centers with specialized equipment and well-experienced medical staff. In low-income countries the high mortality rate from road transport accidents is explained by lack of institutional capacities and poor health care [30].

In our previous papers we have analyzed the dynamics of injury and death rates in road accidents on the example of 6 CEE countries (Germany, Austria, the Czech Republic, Poland, the Slovak Republic and Hungary) for the period 2001-2010 and we have estimated trends for countries and their regions, we have grouped regions into clusters and have built the discriminant models for the analysis of possible changes of regions' distribution into clusters in future [6,7,17]. Eurostat data served as the basis data, reflecting road accidents frequency, injury and death rates for 84 NUTS2 regions of the designated CEE countries.

In 2001 in Germany and Austria lower RTA death rates were observed in comparison to such post-socialist countries as the Czech Republic, Poland, the Slovak Republic and Hungary. The highest rates of mortality among these countries in 2001 were observed in Poland (15,3 per 100 000 of population), and the lowest in the Czech Republic (13,8 per 100 000 of population). Besides that, various reductions of RTA death rates have been achieved for certain countries over the period 2001-2010. Thus, for the given period the most significant changes have been marked in Germany and Austria, where by 2010 they have managed to reduce RTA death rates by 47,6% and 43,9% respectively. Among the countries of the Visegrad group the best results were marked in the Czech Republic, where RTA death rate of population was reduced by 40,6% in 2010 as compared with the level in 2001. In the Slovak Republic and Hungary RTA death rates have been reduced by 37,4% and 35,7% respectively over the given period. The lowest rate of reduction was seen in Poland, where they managed to reduce the RTA death rate only by 26,8% in 2010 in comparison to 2001 [6,7].

Significant reduction of RTA injury rates in CEE countries have been achieved over the period 2001-2010. In Germany the number of injured has been reduced by 102 410 people or by 20,7% over the period of 2001-2010; the reduction in Austria has been 11240 people (20%), in Hungary 3977 people (16,5%), and the largest reductions of RTA injured have been observed in the Slovak Republic (3782, or 35%), Poland (18693, or 27%) and the Czech Republic (8126, or 24%) [6,7].

In the studied CEE countries over a period of 2001-2010, along with significant reduction in the quantity of RTA injured, the number of fatalities has been dramatically reduced, almost by half. The exception is Poland, where over a period of 2001-2010 the number of the dead due to RTA has been reduced by 25% [6,7].

It should be noted that injures and death rates due to road accidents have a prominent regional character, i.e., in a number of regions, due to different social and economic, technology-related and natural factors, death rates are several times higher than in other regions.

We have analyzed the distribution of RTA death rates (per 100 000 of population) for the NUTS2 regions of the studied CEE countries over the period 2001-2010 and established significant differences in RTA death rates in countries, as well as in certain regions [6,7].

In 2001 and 2010 the lowest mortality rates due to RTA per 100 000 of population were seen in the regions of Germany. Thus, in 2001 in Hamburg RTA death rate of population comprised 3,3 per 100 000 of population, and in 2010 in Bremen the rate comprised 2,3 per 100 000 of population. The maximum rate in 2001 in Germany was marked in the Mecklenburg-

Western Pomerania region and comprised 16 per 100 000 of population, and in 2010 the maximum value of this rate was for the Lower Bavaria region and comprised 7,9 per 100 000 of population.

The highest RTA death rates were observed in Poland [6,7]. In 2001 the rate in Łódź Voivodeship comprised 21,2 per 100 000 of population and in 2010 the highest rate was marked in Świętokrzyskie Voivodeship and comprised 18,8 per 100 000 of population. Among Poland regions the lowest RTA death rates were observed in 2001 in Silesian Voivodeship (12,6 per 100 000 of population), and in 2010 in Lower Silesian Voivodeship (6,6 per 100 000 of population) [6,7].

In Austria in 2001 and in 2010 the lowest RTA death rates were noted in Vienna and comprised 7,1 and 3,4 respectively per 100 000 of population. The highest RTA death rates were observed in 2001 in Burgenland region (15,10 per 100 000 of population), and in 2010 in Lower Austria (9,4 per 100 000 of population) [6,7].

The lowest RTA death rates in the Czech Republic were recorded in 2001 and in 2010 in Prague and comprised 11,10 and 5,10 per 100 000 of population respectively. The highest RTA death rates were recorded in the following regions of the Czech Republic: South-West (in 2001 the rates comprised 15,13 per 100 000 of population) and North-East (in 2010 the rates comprised 10,10 per 100 000 of population) [6,7].

The lowest RTA death rates in Hungary were recorded in 2001 in Northern Hungary (12,50 per 100 000 of population), and in 2010 in Central Hungary (7,50 per 100 000 of population). The highest RTA death rates were recorded in 2001 and in 2010 in Southern Hungary (Dél-Alföld) (the rates in 2001 comprised 17,40 per 100 000 of population and in 2010 – 11,60 per 100 000 of population) [6,7].

The lowest RTA death rates in the Slovak Republic were recorded in 2001 and 2010 in its middle part and comprised 12,20 and 6,70 per 100 000 of population respectively. The highest RTA death rates were recorded in 2001 and 2010 in its

Western part and comprised 15,8 and 10,40 per 100 000 of population respectively [6,7].

According to recent data, in 2016 the mortality rate from transport accidents in Austria was 5,2 and in Germany it was 4,1. For the same year in the Visegrad countries the figures were: 5,9 for the Czech Republic; 7,8 for Hungary; 9,7 for Poland and 6,1 for Slovakia [31]. Thus, this indicator is higher in Visegrad countries than in Austria and Germany. In Hungary and in Poland the values of the mortality rate from transport accidents were found to lie in the second quartile, while for Austria, Germany, Czech Republic and Slovakia these values were in first quartile (table A.2, Appendix).

In Ukraine the mortality rate from transport accidents is much higher: in 2016 this indicator was 13,7 per 100 000 inhabitants [31] and this figure was in second quartile (table A.2, Appendix).

As a result of road accidents followed by injury and death we observed the different nature of injury risks for various participants: drivers, passengers, pedestrians, motorcyclists or cyclists. As it appears from these investigations, the highest risk of injury or fatal outcome of a road accident is observed for pedestrians, cyclists and motorcyclists who (in a collision with a motor vehicle) are less protected than drivers or passengers [6]. Nevertheless, the proportion of people killed in road transport accidents subdivided by category of road user is different for different countries (table A.3, Appendix).

The Main Characteristics and Features of Severity Trauma in Road Transport Accidents

In developed countries, from 20 to 80 people per 100 thousand of population die as a result of injury; the number of victims with severe injuries is five times greater [12]. Here we refer to the average numbers for the past few years in terms of deaths and injuries in the developed European countries. Road traffic accidents are the cause of death and serious injuries in about 32% of cases. Injuries resulting from violent actions and attacks account for about 20% of all injuries. Falls from heights account for about 10% of cases, and injuries due to fires and explosions do not exceed 5% of the cases [12].

The typical types of traumatic injury arising as a result of road traffic accidents and other accidents are bleeding, broken bones and spinal fractures, impaired consciousness, cardiac arrest and soft tissue injuries [2,4,8,9,12,27]. A significant proportion of all injuries consists of multiple trauma (polytrauma) and injuries of the chest and abdominal cavities [1,4,14,20]. Heart injuries frequently occur as a result of road traffic accidents, falls from a height, stab wounds and blows in the region around the heart, gunshot and mine-explosive injuries, or as a result of sports injuries [11,18]. Often severe accidents, assault with a weapon, falls or explosions can cause not only blunt trauma but also penetrating injuries of chest and abdomen [4,8,11,16,18].

According to medical reports data, 50% of victims die during the first couple of minutes in cases of severe injury to skull, brain or major blood vessels. In cases of intracerebral bleeding, severe injuries of the thoracic cavity or the abdomen, 30% of victims die during the so-called “golden hour”. Over the next couple of days or weeks, the mortality rate is still high (up to 20%) due to multiple organ failure and systemic inflammatory syndrome. Multiple organ failure is considered to be the most common cause of death in patients with severe trauma, after the first 24 hours [2,12,9,14,29].

In research by Eid H.O. [14], data concerning the nature of anatomic features of the injuries suffered by various participants in a road accident are specified (Table 1). The analysis of 1070 cases of road accident in 2003-2006 was carried out.

As seen from the results of calculations of Fisher’s exact test, in the majority of cases we are able to reject the hypothesis that the anatomical distribution of injuries is the same for all participants in a road accident. Exceptions to this are injuries to the face and thorax, where Fisher’s exact test did not prove the essential distinction between relative indicators. As well as the injures of abdomen and pelvis have p-value of 7%, it is not convincing for conclusion about result of Fisher’s exact test. Nevertheless, this kind of injures should be taken into account for more detail consideration, in sample with more data, where the effect might become significant.

Table 1: Distribution of the number of patients hospitalized as a result of a road accident, subdivided according to the anatomic character of the injury.

Body region	Road user type												p-value for Fisher's exact test
	Driver		Front seat passenger		Rear seat passenger		Pedestrian		Cyclist		Motorcyclist		
	n=395	%	n=153	%	n=130	%	n=229	%	n=80	%	n=73	%	
Head	143	36	45	29	39	30	100	44	32	40	29	40	0,042
Face	111	28	45	29	36	28	46	20	17	21	22	30	0,16
Neck	28	7	5	3	5	4	2	1	2	3	0	0	0,001
Spine	49	12	22	15	16	12	19	8	2	3	5	7	0,002
Thorax	125	32	44	29	36	28	73	32	16	20	15	20	0,15
Abdomen and pelvis	24	6	9	6	16	12	26	11	7	9	4	6	0,07
Upper extremity	124	31	48	31	41	31	80	35	36	45	38	52	0,005
Lower extremity	107	27	43	28	40	31	133	58	44	55	33	45	0,001

Source: Eid H.O., et al. Factors affecting anatomical region of injury, severity, and mortality for road trauma in a high-income developing country: Lessons for prevention. Injury (2008)

For more detailed research see the work of Eid *et al.* [14], where the results of injuries were grouped for two categories of road accident participants: 1) drivers and passengers of cars; 2) pedestrians, cyclists and motorcyclists. It was shown that a considerably higher percentage of injuries to the head and to the upper and lower extremities is observed among the second category of road accident participants, while for the first category a higher percentage of injuries to the face, neck and spine is observed. As for the frequency of injuries to the thorax, abdomen and pelvis the difference was statistically insignificant, i.e. approximately identical proportions of these injuries to victims are observed from the first and second categories.

Table 2 provides selective data on the distribution of injuries suffered by pedestrians as a result of a road accident in different countries [14].

Table 2: Comparative analysis of the distribution of the kind of injury sustained by pedestrians as a result of road accidents worldwide.

Body region	China (%)	Europe (%)	Australia (%)	Japan (%)	USA (%)
Head	31,5	29,5	39,3	28,6	32,7
Face	5,8	5,3	3,7	2,4	3,7
Neck	0,8	1,8	3,1	4,5	0,0
Thorax	10,9	11,6	10,4	8,5	9,5
Abdomen	6,2	3,8	4,9	4,8	7,7
Pelvis	2,6	7,9	4,9	4,5	5,3
Upper extremity	9,4	8,1	8,0	9,0	7,9
Lower extremity	32,8	31,3	25,8	37,2	33,3

Source: WHO (2004)

As seen from Table 2, there are some, not very significant, differences between countries. On the basis of the given data it is clear that the two commonest types of injuries are injuries to the head and lower extremities; then follow injuries to the thorax, the upper extremities and the abdomen.

Considering that, in severe road accidents, victims have difficult multiple traumas, the chance of survival significantly depends on the efficiency and competence of those rendering emergency first aid. In turn, the coordination of police services, paramedical staff and emergency aid work depends on many factors and significantly differs in various countries. In economically less developed and poorer countries, more than half of the victims of severe road accidents die during the first hours after the incident. Thus, according to Kumar *et al.* [21], among the victims killed by severe road accidents in India, 39,84% died on the spot and 28,51% within the first days. Only 8,47% of victims survived for between 4 and 7 days after a severe road accident and only 8,82% for between 8 and 14 days.

In our research we provided the comparative analysis of archival material of the Forensic Expertise Department for victims in fatal road transport injuries in Kharkov region for 1989 and 2013. The analysis showed that, of the total number of fatalities, the proportion caused by a car accident was 54,4% in 1989 and 36,5% in 2013. The total number of deaths from road transport accidents registered in Kharkov Forensic Expertise Department was 285 cases in 1989 and 277 in 2013.

Analyzing these data, we can conclude that there is some tendency towards a reduction in the absolute number of deaths from injury involving cars from 1989 till 2013, but their shares in the collection of road accidents with fatal consequences were reduced from 54,4% in 1989 to 36,5% in 2013. The decline by more than a third of the number of fatalities in car accidents in 25 years can be explained by the influence of many factors, the combination of which has led to qualitative changes in the structure of road traffic injuries.

Over 25 years the car fleet has changed dramatically in Ukraine and Kharkov region; now foreign-made cars dominate on Ukrainian roads. Most modern cars have become high-speed in comparison with previous cars of domestic production (the well-known brands produced in the USSR were Volga, Moskvich, Zhyguli, Lada, Niva, etc.). Modern cars are designed with safety in mind: the hood of car is tilted down and forward, the bulk of the cars have a low landing and, most importantly, a much-improved system of active and passive protection. The new principles of the automobile industry have led to changes in the structure and nature of road fatalities.

For this part of the research and description of forensic issues of the data we used 155 cases of fatal road transport accidents in 1989 and 101 cases of fatal road transport accidents in 2013. The main types of fatal motor vehicle injuries in 1989 were damage from being struck by a moving car (58,7%) and damage occurring inside the cabin of the car (34,8%). The breakdown by type of injury in 2013 was as follows: damages from being struck by a car (63,3%), damage inside the cabin (32,7%), combined types of auto injuries (4%).

It is possible to observe some changes in the nature of the trauma from the impact of a moving car, namely that there has been a decrease in the proportion of damage to the facial and brain divisions of the skull and damage to the membranes of the brain and bruises. At the same time, the incidence of bruises and wounds has increased slightly. That is, in 1989, more serious injuries such as damage to the skull and brain membranes were observed, whereas in 2013, surface injuries - bruises, bleeding, and wounds - were more common. Among the reasons that led to these changes, important factors are the structural changes to the body of modern cars and improved systems of active and passive safety. Therefore, car trauma has acquired new morphological characteristics.

These data allow us to conclude that the number of external lesions (skin abrasion, bruises, wounds) has decreased, but there has been an increase in the share of fractures of the bones of the facial and brain departments of the skull and intracerebral lesions, especially brain tissue. This can be explained on the one hand by the more secure fixing of the driver and passengers in their seats with personal protective equipment (belts and airbags), and on the other hand by the high dynamic characteristics of modern cars, which is accompanied by an increase in the kinetic energy of the objects of automobile injury.

The nature of damage to the body and internal organs is one of the most informative elements in establishing the type of car injury, the mechanism of causing damage. Therefore, our study focused on the internal and external damage of the body. In 1989, the following injuries were most commonly observed as a result of damage from a moving vehicle: bruising - 54 cases (34,84%), hemorrhage - 51 cases (32,9%), rib fractures - 35 cases (22,58%), pelvic injury - 22 cases (14,19%), lung injury - 18 cases (11,61%), liver injury - 13 cases (8,39%), and breast fractures - 10 cases (6,45%) and only a small number of spine fractures - 9 cases (5,81%), heart and wound injuries - 6 cases (3,87%), spinal cord injury - 5 cases (3,23%), spleen damage - 3 cases (1,94%), and in 1 case (0,65%) kidney damage was observed.

In 1989, the injuries inside the cabin of car were characterized by hemorrhage - 38 cases (24,52%), rib fractures - 33 cases (21,29%), skin abrasion - 32 cases (20,65%), liver damage - 27 cases (17,42%), bruising - 21 cases (13,55%), lung injury - 18 cases (11, 61%). Rarely forensic experts revealed spleen injuries - 12 cases (7,74%), breast fractures - 11 cases (7,1%), pelvis and kidney damage - 8 cases (5,16%), heart, spinal cord injury and wound - 7 cases (4,52%) and spinal fractures - 6 cases (3,87%).

In 2013 injuries caused by parts of a moving car were the following: bleeding - 42 cases (41,58%), rib fractures - 36 cases (35,64%), skin abrasion - 24 cases (23,76%), pelvis - 20 cases (19,8%), liver damage - 19 cases (18,81%), lung injury, spinal cord fractures, and spinal cord injury - 18 cases (17,82%), bruises - 13 cases (12,87%), kidney damage - 10 cases (9,9%). In car cabin the injures were: hemorrhage - 31 cases (30,69%), rib fractures - 29 cases (28,71%), liver and lung damage - 18 cases (17,82%), fractures of the sternum - 13 cases (12,87%), skin abrasion - 12 cases (11,88%). Spinal injuries and other were less likely to occur, namely: spinal injuries – 7 cases (6,93%), injuries of heart - 7 cases (6,93%), damage to the spinal cord - 5 cases (4,95%), kidney damage - 3 cases (2,97%).

According to the results of the comparative analysis for 1989 and 2013 for the cases of injured pedestrians, it can be concluded that in 2013 the number of cases of damages, such as: spinal fractures with damage to the spinal cord and damage to the abdominal organs (liver, spleen) and retroperitoneal space (kidney) increased significantly in comparison with 1989. At the same time, the number of cases of bruising, bleeding and wounds has decreased for the cases of injured pedestrians. This indicates an increase in the level of energy of the shaking of the body received by pedestrians and an increase in the slipping elements in the general mechanism of this type of car injury. The logical explanation for such changes in the mechanism of injury is that the interaction between the pedestrian and the vehicle occurs at higher speeds than in earlier times.

The differences in the nature of injuries in traumas in the car cabin over the past period are less pronounced. Decreases in the appearance of external damage (skin abrasion, bruising), absence of wounds and some reduction of damage to the liver, spleen, kidneys were observed too. These changes in the morphological picture of the injury can be explained by the effectiveness of the safety of the driver and passengers of cars.

In 1989 the most common causes of death from the impact of a moving vehicle were: shock - 19 cases (12,26%), brain injury – 13 cases (8,39%) and pulmonary heart failure - 13 cases (8,39%), intracranial hemorrhage – 12 cases (7,74%), swelling - dislocation of the brain – 7 cases (4,52%), pneumonia – 5 cases (3,23%) and acute blood loss - 5 cases (3,23%), body trauma incompatible with life – 3 cases (1,94%) and open traumatic brain injury - 3 cases (1,94%).

In 2013, in the cases of fatal trauma caused by a moving vehicle, the most common causes of death were: shock - 13 cases (12,87%), body trauma incompatible with life – 10 cases (9,9%), edema-dislocation of the brain – 5 cases (4,95%), compatible and closed blunt trauma of the body – 4 cases (3,96%), craniocerebral trauma - 5 cases (4,95%), acute blood loss - 3 cases (2,97%), acute cerebrovascular accident - 3 cases (2,97%), pulmonary heart failure – 2 cases (1,98%), rupture of the thoracic aorta – 2 cases (1,98%), rupture of the spinal cord, rupture of the spine – 2 cases (1,98%), multiple organ failure – 2 cases (1,98%), destruction of the skull – 2 cases (1,98%), multiple head injuries - 2 cases (1,98%). It is apparent that shock remained the most common cause of death in this type of car injury, and the proportion caused by body trauma incompatible with life was also high. It can be concluded that in 2013 pedestrians in many cases were seriously injured due to the considerable energy of impact with the vehicle.

The most common causes of death inside the car cabin in 1989 were: shock - 12 cases (7,74%), pulmonary heart failure – 7 cases (4,52%), intracranial hemorrhage – 6 cases (3,87%), injures of brain – 4 cases (2,58%), acute blood loss – 3 cases (1,94%), ruptures of the internal organs - 3 cases (1,94%).

According to the analysis in 2013 the most common causes of injures and death inside the car cabin were: body injury incompatible with life - 8 cases (7,92%), shock – 5 (4,95%), edema-dislocation of the brain – 3 cases (2,97%), acute blood loss – 3 cases (2,97%), closed blunt body trauma – 3 cases (2,97%), multiple chest trauma - 3 cases (2,97%), acute cerebral circulation disorders in 2 cases (1,98%).

Thus, the first place among the causes of death in a car accident in 1989 was occupied by shock, but in 2013 trauma incompatible with life was dominated. This shows that in 2013 the number of cases of significant injuries to the driver and passengers has increased. This condition can be explained by the increase in the speed of cars against the background of neglect of safety measures (seat belts, absence of airbags).

The Problems of Diagnostics, Clinical Manifestation and Consequence of Trauma Disease

There are different approaches for the timely assessment of the severity of trauma of the victims and the provision of specialized medical care [2,9,12,14,20].

Usually experts noted the problem of polytrauma or major trauma. Polytraumas often are associated with motor vehicle crashes. This is because car crashes often occur at high velocities, causing multiple injuries. Major trauma is any injury that has the potential to cause prolonged disability or death. There are many causes of major trauma, blunt and penetrative, including falls or motor vehicle collisions [2,12]. The well-known 'trauma triad of death' is very dangerous [8,12]. This is a medical term describing the combination of hypothermia, acidosis and coagulopathy [8,12]. According to the many studies of this effect, this combination (hypothermia, acidosis and coagulopathy) increased the mortality rate for patients with severe traumatic injuries. Thus, severe bleeding in trauma diminishes oxygen delivery, and may lead to hypothermia. In addition, the coagulation cascade, preventing blood from clotting, should be taken into account. The next problem is metabolic acidosis as a result of a complicated biochemical reaction in the body's cells under the condition of a low level of blood-bound oxygen and nutrients (hypoperfusion). An increase in acidity damages the tissues and organs of the body and can reduce myocardial performance, further reducing the oxygen delivery [8,27,29].

At the site of a road accident it is very difficult to assess the severity and features of the traumas, especially for people who try to provide first aid and do not possess any medical knowledge and skills. That is why is very important to give special courses of first aid for students in colleges and universities, as well as to educate drivers of vehicles and give them knowledge of the basics of first aid in road accidents [12].

Emergency staff or paramedical personnel assess vital signs defining the color-coded triage (from green to red). In this triage they evaluate such indicators as:1) RR: respiratory rate; 2) SpO2: saturation of peripheral oxygen (pulse oxymetry); 3) HR: heart rate; 4) GCS: Glasgow Coma Score; 5) Tp: temperature. Abnormal vital signs, which are located in the red or orange color zones, are strong predictors for intensive care unit admission and in-hospital mortality in adults triaged in the emergency department. A patient with no essential differences in vital signs (the yellow zone of the scale) should additionally be checked by a doctor.

As a simple approach it is possible to use the Injury Severity Score (ISS). This is an example of a trauma scoring system. This assigns a score from 0 to 75 based on the severity of injury to the human body divided into three categories: A (face/neck/head), B (thorax/abdomen), C (extremities/external/skin). Each category is scored from 0 to 5 using the Abbreviated Injury Scale, from uninjured to critically injured, which is then squared and summed to create the ISS. For example, if the Injury Severity Score (ISS) is greater than or equal to 16 we talk about polytrauma. Depending on the triage situation, this may indicate either that the patient is a first priority for care, or that he or she will not receive care owing to the need to conserve care for more likely survivors [9].

In a hospital or trauma center a collection of scales or models can be used for the evaluation of the severity of injuries. The most well-known approaches are: AIS-90 (Abbreviated Injury Scale), ISS (Injury Severity Score), RTS (Revised Trauma Score), APACHE II (Acute Physiology and Chronic Health Evaluation), SAPS II (Simplified Acute Physiology Score), TRISS (Trauma and Injury Severity Score), ASCOT (A Severity Characterization of Trauma), LODS (Logistic Organ Dysfunction Score), 24-hour ICU Trauma Score, TRIOS 4 (Three days Recalibrated ICU Outcomes Score), Mortality Probability Model, etc. [2,9-11,19,20,22,25]. Some of these methods are based on the development of scales and logistic models to assess the severity of injuries and the probability of various outcomes with the help of expert or statistical methods.

On admission to hospital any trauma patient should immediately undergo x-ray diagnosis of their cervical spine, chest, and pelvis, commonly known as a 'trauma series', to ascertain possible life-threatening injuries. Examples would be a fractured cervical vertebra, a severely fractured pelvis, or a haemothorax. Once this initial survey is complete, x-rays may be taken of the limbs to assess the possibility of other fractures. It also is quite common in severe trauma for patients to be sent directly to CT or a surgery theatre, if they require emergency treatment [3,8,12,20,32].

Depending on the severity of injury, rapid management and transportation to an appropriate medical facility (called a trauma center) may be necessary to prevent loss of life or limb. The initial assessment is critical and involves a physical evaluation; it may also include the use of imaging tools to determine the types of injuries accurately and to formulate a course of treatment [12,32].

In our research we focused more on the problem of polytrauma and application of new approaches for the evaluation of the severity of injuries and the prediction of outcomes.

Polytrauma and multiple trauma mean multiple traumatic injuries, such as a serious head injury in addition to a serious burn.

Polytrauma causes asystemic reaction in the body, which is determined by three components [8,12]:

- Microcirculation failure because of hemorrhagic shock, hypovolemia, hypoperfusion and hypoxia with consequent development of metabolic impairment
- Immune response, taking the form of systemic inflammatory syndrome
- Coagulopathy caused by the injury.

Today the management of patients with multiple trauma (polytrauma), almost regardless of its severity, is reduced to the standardized approach, which includes adequate external and internal breathing, and efficient hemodynamics (ABC-protocol) [12]. This should be followed by the correction of secondary pathogenic mechanisms which occurred at the site of the injury and are associated with a decrease in adequate circulation volume, in the cessation of bleeding and in the sequestration of fluids in the "third space" – the correction and stabilization of cardiac performance, the correction of electrolyte abnormalities and the acid-salt balance.

According to various sources and treatment protocols for patients with severe polytrauma, one of the priorities is to ensure hemodynamic and respiratory functions, which are often carried out in these patients using artificial pulmonary ventilation [3,8,12].

Application of Quantitative Models for the Analysis of Severity of Injures and Prediction of Outcomes

During the last few decades, a variety of mathematical and statistical methods have been widely used in medicine, including emergency medicine and the resuscitation of severely injured patients [10,11,19,25]. It should be mentioned that in foreign studies, methods of survival analysis such as life tables, the Cox model, Kaplan-Meier estimation, exponential, normal and lognormal regression are used frequently [5,19,26].
As seen from the sources above, most of these predictive models were developed by Western scholars and some of the models and scales have been developed in the 70s and 80s [5,9,19,26]. It should be noted that predictive models, developed by Western scholars, are not completely universal for the following reasons: estimation of parameters and characteristics of the models, based on statistical methods, essentially depend on the model specification, features of sample data, characterizing the condition of the victims, the level of development of the national health system and emergency medical care.

Considering these factors, it is also reasonable to develop such models on the basis of contemporary national databases, which allow to take into account the specifics of the level of development of the national health care and emergency medical services, characteristics of the condition of the victims, the most common trauma, complications, comorbidities, etc. Examples of such developments are the classification of the severity of traumatic shock, proposed by I.A. Eryuhin and S.A. Shlyapnikov [15], and the logistic models obtained by H. Eid et al (Eid H.O., 2008) for predicting the level of mortality of victims of traffic accidents according to data of the hospital Al Ain in the United Arab Emirates [14].

In Ukraine, these methods are not used sufficiently often in medical research work, which is why there is a need for more complete awareness about the application of mathematical and statistical tools.

In this part of the research into the severity of injures in road transport and other accidents and prediction of outcomes we demonstrate examples of the application of survival analysis, logit-models and discriminant analysis [13,28].

Survival analysis is traditionally frequently used in medical and biological research, insurance and reliability theory. The problem under investigation is that of studying the survival time, which depends on several factors and may follow any of a number of different distributions. In these tasks baseline data on survival time are divided into two types: full, which correspond to death or failure of the device, and incomplete (censored), which suggests that the object under study remained alive until a particular point in time, and further contact with him was lost. For example, in clinical research, data listing accident victims who have been discharged or transferred to other departments provides an example of censorship.

By way of an example of the use of survival analysis models we present data from about 373 patients admitted with severe injuries to the V.T. Zaicev Institute of Emergency surgery. There were 263 (70,51%) favorable outcomes (survivors) and 110 (29,49%) deaths. The database provides information on patients with the following injuries: open injury – 285 cases (76,41%); closed injuries – 80 cases (21,45%), and compound injuries – 8 cases (2,14%). The ages of the patients range from 7 years to 84 years, the distribution of the affected age group was close to normal, and the average age was 34 ± 1,17 years.

In this study, we selected a subgroup of patients in critical condition, most of them undergoing artificial pulmonary ventilation (APV), and determined the duration of the procedure. For this subsample we identify two types of outcomes, or two types of data: complete (the patient died) or censored (the patient survived). For the calculations associated with the survival analysis model we used the program Statistica [5].

Table 3 shows the sample distribution of the patients admitted to the V.T. Zaicev Institute of Emergency surgery who required the use of artificial pulmonary ventilation. Twelve time intervals were selected using the Statistica program, with a difference of 11 minutes. As seen from Table 3, artificial pulmonary ventilation (APV) was performed during the first time interval, on 181 patients, 27 of whom died within the first 11 minutes. Thus 181 people were put on the APV, 27 of them died within the first 11 minutes of starting the artificial pulmonary ventilation, 129 were taken off the APV in the first 11 minutes because they no longer needed it. The proportion of deaths in the first interval was 0,232. This proportion is computed as the ratio of the number of cases failing in the respective interval, divided by the number of cases at risk in the interval. In other words, it is the number dying divided by the number exposed, or 27/116,5 [13].

The number exposed, or number of cases at risk, is the number of cases that entered the respective interval alive, minus half of the number of cases lost or censored in the respective interval. Thus, the number of exposed is calculated as: number entering – (number withdrawn/2). Then 25 patients were still on the APV after 11 minutes and started on the second interval, 3 people died in the 2nd interval, 11 were taken off because they didn't need it and 11 were still on the ventilator after 22 minutes. In this interval the proportion of deaths was 0,154 (3/19,5).

A detailed analysis shows that these were the most severe cases, with injuries incompatible with life. In the third time interval, when the duration of the application of the ventilator exceeded 22 min. but was less than 33 min., the number of deaths was 3 and proportion of deaths was 0,3 (3/10).

Table 3: Characteristics of survival time distribution among victims after APV.

Time interval number	Start of time interval, min.	Number entering	Number with-drawn	Number exposed	Number dying	The proportion of dead	The proportion of survivors	The cumulative proportion of survivors	Probability density	Hazard Rate
1	0	181	129	116,5	27	0,232	0,768	1	0,0212	0,024
2	11	25	11	19,5	3	0,154	0,846	0,768	0,0108	0,0153
3	22	11	2	10	3	0,3	0,7	0,65	0,0179	0,0324
4	33	6	0	6	0	0,083	0,917	0,455	0,0035	0,008
5	44	6	0	6	0	0,083	0,917	0,417	0,0032	0,008
6	55	6	0	6	2	0,333	0,667	0,382	0,0117	0,0367
7	66	4	1	3,5	1	0,286	0,714	0,255	0,0067	0,0306
8	77	2	0	2	0	0,25	0,75	0,182	0,0042	0,0262
9	88	2	0	2	0	0,25	0,75	0,137	0,0031	0,0262
10	99	2	0	2	1	0,5	0,5	0,102	0,0047	0,0611
11	110	1	0	1	0	0,5	0,5	0,051	0,0023	0,0611
12	120	1	0	1	1	0,5	0,5	0,026	-	-

Source: *data processed by the authors in Statistica*

In the Table 3 the cumulative proportion of survived is given. This is the cumulative proportion of cases surviving up to the respective interval. Since the probabilities of survival are assumed to be independent across the intervals, this probability is computed by multiplying out the probabilities of survival across all previous intervals. The resulting function is also called the survivorship or survival function [1].
The probability density is the estimated probability of failure in the respective interval, computed per unit of time, that is:

$$F_i = \frac{P_i - P_{i+1}}{h_i}.$$

In this formula, F_i is the respective probability density in the i'th interval, P_i is the estimated cumulative proportion surviving at the beginning of the i'th interval (at the end of interval (i-1)), P_{i+1} is the cumulative proportion surviving at the end of the i'th interval, and h_i is the width of the respective interval [5].

Then the hazard rate was calculated (see Table 3.). The hazard rate is defined as the probability per time unit that a case that has survived to the beginning of the respective interval will fail in that interval. Specifically, it is computed as the number of failures per time units in the respective interval, divided by the average number of surviving cases at the mid-point of the interval [5].

Analyzing the dynamics of the proportion of victims who died, as a function of APV duration (Table 3), we can see its non-linear character. So, in the first interval (up to 11 min APV), the proportion of deaths was 0,232; in the second interval (from 11 to 22 minutes of pulmonary ventilation), the proportion of deaths was 0,154; in the third interval (from 23 to 32 minutes), the proportion of deaths almost doubled, to 0,3; in the 4th and 5th intervals (33- 54 minutes APV), the proportion of deaths decreased and remained stable at the level of 0,083; then in the 6th interval (55 - 65 min APV), the proportion of deaths increased again to 0,333 and remained fairly high for the next interval. Isolation of these critical time periods of APV, where there is a sharp jump in the proportion of deaths, is important for analyzing the prevention of various complications and the application of additional resuscitation.

Table 3 gives a good indication of the distribution of failures over time. However, for predictive purposes it is often desirable to understand the shape of the underlying survival function in the population. The major distributions that have been proposed for modeling survival or failure times are the exponential distribution, linear exponential distribution, the Weibull distribution of extreme events, and the Gompertz distribution [5].

The regression procedure for fitting the four theoretical distributions to the life table is based on algorithms proposed by Kennedy and Gehan (1971) and discussed in detail in Lee (1980) [5]. Basically, the hazard functions (specifically, the logarithmic transforms of the hazard functions) of all four theoretical distributions are linear functions of the survival times (or log-survival times). If we set $y = h(t)$ or $y = \log h(t)$, then all four models can be stated in the general form: $y = a + b \cdot x$. Gehan and Siddiqui (1973) suggest weighted least squares methods to fit the parameters of the respective models to the data [5]. Specifically, the program Statistica will minimize the quantity:

$$WSS = \sum_i \left(w(i) \cdot [y(i) - a - b \cdot x(i)]^2 \right)$$

Three different weights are used in the estimation:

(1) $w(i) = 1$ (unweighted least squares)

(2) $w(i) = 1 / v(i)$

(3) $w(i) = n(i) \cdot h(i)$,

where $v(i)$ is the variance of the hazard estimate, and $h(i)$ and $n(i)$ are the interval width and number of observations exposed to risk in the i'th interval, respectively [5].

In our analysis we tested the results of fitting the Weibull model to the data with different weightings (weight 1, weight 2, weight 3).

Table 4 shows the estimates of the Survival Function for our data.

Table 4: Estimates of Survival Function (Model: Weibull).

Time interval number	Interval Start	Weight 1	Weight 2	Weight 3
1	0	1	1	1
2	10,909	0,868	0,783	0,775
3	21,818	0,709	0,589	0,610
4	32,727	0,561	0,436	0,484
5	43,636	0,434	0,319	0,385
6	54,545	0,329	0,231	0,307
7	65,455	0,246	0,167	0,245
8	76,364	0,181	0,119	0,196
9	87,273	0,132	0,085	0,157
10	98,182	0,095	0,060	0,126
11	109,091	0,067	0,042	0,102
12	120	0,047	0,030	0,082

Source: *data processed by the authors in Statistica*

Figure 1 represents the estimates of the Survival Function.

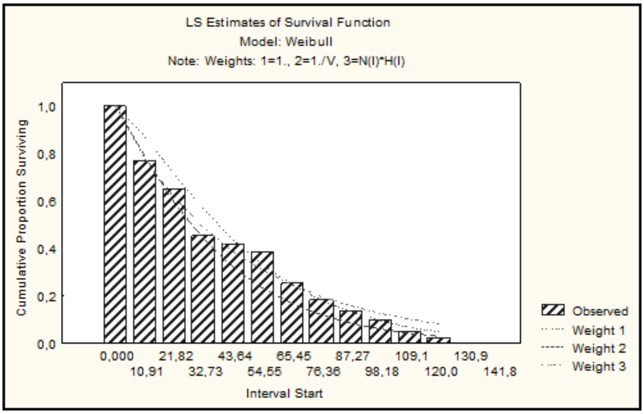

Figure 1: The Estimates of Survival Function.

Figure 2 represents the dynamics of the proportion of victims who die, as a function of APV duration and the results of fitting the Weibull model to the data with different weightings (weight 1, weight 2, weight 3).

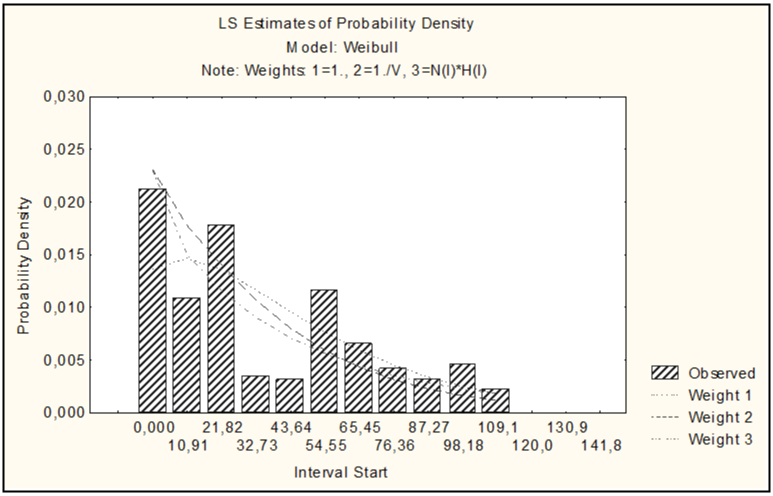

Figure 2: Dynamics of the proportion of victims who die, as a function of APV duration.

As we can see from the data presented in Table 5, for all three weighting schemes (weight 1, weight 2, weight 3) there was no statistically significant difference between the fitted Weibull distribution and the empirical distribution, using the chi-square test.

However, the closest to the empirical distribution is the distribution fitted using the third weighting scheme (weight 3), where the value of the Chi-square test statistic is lowest.

Table 5: The parameter estimates for the Weibull model.

Note: Weights: 1=1., 2=1./V, 3=N(I)*H(I)									
		Std.Err.		Std.Err.	Covarnce	Log-			
	Lambda	Lambda	Gamma	Gamma	Gam-Lam	Likelhd.	Chi-Sqr.	df	p
Weight 1	0,006624	0,006664	1,280725	0,254336	-0,00164	-94,9192	14,35808	9	0,110
Weight 2	0,01717	0,00909	1,111659	0,15621	-0,00136	-91,5666	7,652955	9	0,567
Weight 3	0,026173	0,015945	0,952644	0,181525	-0,00279	-90,5439	5,607468	9	0,775

Source: *data processed by the authors in Statistica*

The Kaplan-Meier method of estimation was also carried out on the data in this investigation. Unlike the method of life tables, the method proposed by Kaplan and Meier does not require the subdivision of survival times into intervals. Estimation of the survival function is given by the following formula:

$$S(t) = \prod_{\forall j} \left[\frac{(n-j)}{(n-j+1)} \right]^{\delta(j)},$$

where is the estimate of the survival function, *n* is the number of events (observations), *j* is the position of the event when all events are arranged in increasing time order, and δ(*j*) is equal to 1 if the outcome of the *j*th event was that the victim died and 0 otherwise.

Based on the Kaplan-Meier estimates we obtained a graph of victims' survival, as a function of the duration of pulmonary ventilation (Fig. 3).

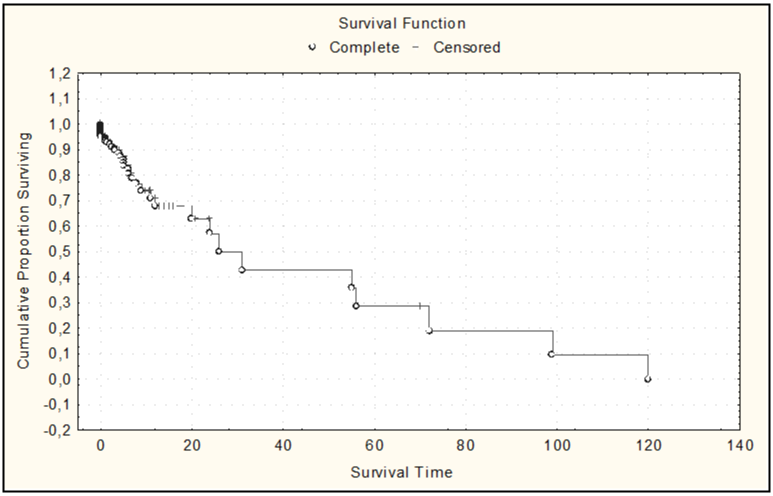

Figure 3: Victims' survival, as a function of the duration of APV.

Since the survival function values are obtained by multiplying estimates of survival probabilities of previous events ordered for the relevant victims, the graph shown in Fig. 2 shows that the value of the function is initially equal to 1 (100%), then within 12 min the value falls to 0,67 (67%). After that, the values of the survival function, although they are decreasing, take the form of a step function and decrease less rapidly than in the first interval. In order to assess how the probability of the various outcomes for the victim is influenced by other factors in addition to the time of the APV, we constructed a Cox proportional hazards model.

In this case, the time intensity function of APV (variable X8) depends on a number of factors included in the model: variable D28 (the presence of lung injury), D29 (the presence of heart injury), X9 - the quantity of blood loss (ml), and X6 - blood pressure value before surgery.

The results of the Cox proportional hazards model are presented in Table 6.

As can be seen from table 6, the value of the chi-square test statistic for this model is statistically significant at the level of error less than 1%. Of the factors included in the model two variables have a statistically significant effect on the duration of APV and the possible outcome for the victim: D28 (the presence of lung injury) and X6 (blood pressure before surgery). It should be noted that factors such as the presence of cardiac injury (D29) and the amount of blood loss (X9) are correlated with an arterial blood pressure index, which is measured in patients before surgery. In other words, the lack of statistical significance of the factors D29 and X9 is explained by the effect of multicollinearity, i.e., a linear correlation with the X6 factor. Factor X6 in victims can be determined fairly quickly, while the measurement of blood loss or determination of the presence of cardiac injury requires much more time and the application of additional diagnostic methods.

Table 6: Cox proportional hazard model results.

Dependent Variable: X8 (new_sh~1.sta) Censoring var.: Y Chi = 15,3084 df = 4 p = ,00411						
		Standard		exponent	Wald	
	Beta	Error	t-value	beta	Statist.	p
D28 (lung injury)	0,659172	0,365658	1,802699	1,93319	3,249722	0,071445
D29 (heart injury)	0,201824	0,442106	0,456506	1,223632	0,208398	0,648029
X9 (quantity of blood loss)	0,000165	0,000196	0,844198	1,000165	0,71267	0,398565
X6 (blood pressure value before surgery)	-0,01815	0,005747	-3,15759	0,982018	9,970396	0,001592

Source: *data processed by the authors in Statistica*

In addition to these factors, it is possible to include in the survival model other quantities which are important in monitoring patients' vital functions and in preventing the development of complications in the early and late post-traumatic periods. When changing the set of indicators and factors affecting the condition of patients with severe polytrauma, it is possible to use the package Stastistica to build a variety of survival functions for patients with different risk factors.

Another important area of research is the study of patients' survival rates during the late post-traumatic period.

Whilst the scheme for the correction of traumatic injuries is well developed and the treatment scheme works well enough, the post-traumatic period and the associated adaptation pathological processes are not. For all that, they are of fundamental importance in the development of post-traumatic syndrome. Their severity may be only weakly related to the severity of the injury, because they are also associated with the body's systemic adaptive reaction, which may be a damaging factor by not working properly.
In addition, using the previous sample (see description earlier) we had the aim of studying the possibility of developing and applying various statistical models for the prediction of outcomes in the case of various categories of trauma. Thus, according to the sample of 373 patients, we knew that 263 (70,51%) had positive outcomes (remained alive), while 110 (29,49%) had fatal outcomes. The existing database contains information about victims with the following types of injury: open trauma – 285 cases (76,41%); closed injury – 80 cases (21,45%), combined injury – 8 cases (2,14%) [28].

The mechanism of injuries was as follows: S-i (stab-incised trauma) – 261 cases (69,97%); Gun (gunshot trauma) – 27 cases (7,24 %) , TA (d) (traffic accident – driver) – 13 cases (3,49%); TA (p) (traffic accident – pedestrians) – 18 cases (4,83 %); RW (railway trauma) – 8 cases (2,14 %); Kat (katatrauma) – 15 cases (4,02 %); B (beatings, bruises) – 11 cases (2,95 %); SBM (struck by mechanisms) – 11 cases (2,95 %), An (wounds, caused by animal's bite) – 3 cases (0,8%) and Unkn (unknown mechanism of injury) – 3 cases (0,8%) [28].

According to the results of the available sample, the features of the distribution and the mode of received injuries were studied extensively. Thus, there were 154 cases of polytrauma (41,29%); 243 cases of abdominal trauma (65,15%); 254 cases of chest trauma (68,1%); 28 cases of craniocerebral trauma (7,51%); 20 cases of pelvic trauma (6,17%); 23 cases of orthopedic trauma (6,17%) and 6 cases of spinal trauma (1,61%).

Table 7 shows the distribution of types of trauma depending on the mechanism of trauma.

Sampling the data of 373 patients used in our study, the following distribution of trauma of viscera was observed: trauma of lungs (TrL) – 94 cases (25,2%); trauma of heart (TrH) – 61 cases (16,35%); trauma of parenchymatous organs (TrParenh) – 138 cases (37%); trauma of liver (TrLiv) – 86 cases (23,06%); trauma of pancreas (TrPan) – 31 cases (8,31%); trauma of hollow organs (TrHol) – 98 cases (26,27%) and trauma of bowel (TrBow) – 28 cases (7,51%).

Table 8 shows the distribution of outcomes depending on the type of trauma.

Table 7: Distribution of types of trauma depending on the mechanism of trauma.

	Polytr	AbdomTr	ChestTr	Cr-Cer.Tr	PelvTr	OrthopTr	SpinTr
S-i	79 (30,27%)	172 (65,9%)	171 (65,52%)	3 (1,15%)	-	-	-
Gun	16 (59,26%)	18 (66,67%)	21 (77,78%)	2 (7,41%)	1 3,7%)	1 (3,7%)	-
TA (d)	11 (84,62%)	8 (61,54%)	12 (92,31%)	5 (38,46%)	2 (15,38%)	4 (30,77%)	1 (7,69%)
TA (p)	18 (100%)	10 (55,56%)	16 (88,89%)	9 (50%)	6 (33,33%)	8 (44,44%)	1 (5,56%)
RW	7 (87,5%)	5 (62,5%)	4 (50%)	1 (12,5%)	4 (50%)	3 (37,5%)	1 (12,5%)
Kat	7 (46,67%)	7 (46,67%)	11 (73,33%)	3 (20%)	4 (26,67%)	2 (13,33%)	2 (13,33%)
B	2 (18,18%)	9 (81,82%)	4 (36,36%)	1 (9,09%)	1 (9,09%)	1 (9,09%)	-
SBM	6 (54,55%)	7 (63,64%)	8 (72,73%)	1 (9,09%)	1 (9,09%)	2 (18,18%)	1 (9,09%)
An	3 (100%)	2 (66,67%)	3 (100%)	1 (33,33%)	-	1 (33,33%)	-
Unkn	2 (66,67%)	3 (100%)	1 (33,33%)	-	1 (33,33%)	1 (33,33%)	-

Source: *data processed by the authors*

Table 8: Distribution of outcomes depending on the type of trauma.

Outcome	Polytr	AbdomTr	ChestTr	Cr-Cer.Tr	PelvTr	OrthopTr	SpinTr
F	103 (66,88%)	168 (69,14%)	177 (69,69%)	19 (67,86%)	14 (70,00%)	15 (65,22%)	3 (50%)
A	51 (33,12%)	75 (30,86%)	77 (30,31%)	9 (32,14%)	6 (30,00%)	8 (34,78%)	3 (50%)
All	154 (100%)	243 (100%)	254 (100%)	28 (100%)	20 (100%)	23 (100%)	6 (100%)

Source: *data processed by the authors*

Positive outcomes (alive) are marked as «A» and fatal outcomes as «F» in the current table.

The status of the victim and the level of medical care necessary in this situation affect the result of the outcome. Scale ISS is often used to assess the severity of trauma.

Figure 4 shows the distribution of victims by the level of severity of trauma in the original database (according to the ISS – Injury Severity Score – scale).

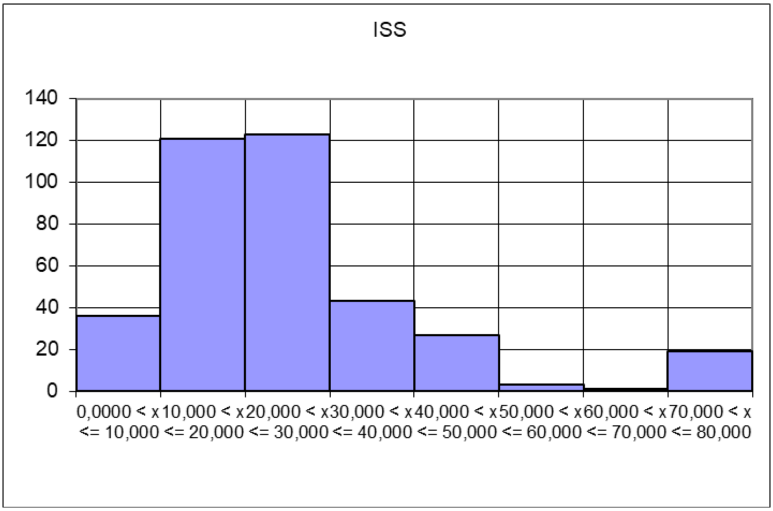

Figure 4: Distribution of victims by the level of severity of trauma (ISS scale).

According to the distribution shown in Fig. 4, 36 cases (9,65%) fell into the interval where the values of ISS were less than 10; 121 (32,44%) and 123 (32,98%) cases fell in the intervals $10 < ISS \leq 20$ and $20 < ISS \leq 30$ respectively; 43 cases (11,53 %) fell into the interval $30 < ISS \leq 40$; 27 cases (7,24%) fell into the interval $40 < ISS \leq 50$; 3 cases (0,8%) fell into the interval $50 < ISS \leq 60$ and the number of cases where the ISS value exceeded 60, was 20 (5,26%).

The average value of the ISS index in the sample for 373 patients was 25,99 ± 1,53.

In the group of victims with a positive outcome the average value of ISS was 21,29 ± 1,15, and in the group of victims with fatal outcome it was 37,26 ± 3,68.

The application of Student's and Fisher's criteria to determine significance of statistical difference in the average ISS index for victims with positive and fatal outcomes revealed that there are significant differences of ISS in these groups (the value of Student statistic was $t = -10{,}65$ with $p < 0.01$ and that of the Fisher statistic was $F = 4{,}23$ with $p < 0.01$).

The indicators of the degree of shock in the groups of victims were distributed as follows (Table 9):

Table 9: Distribution of degree of shock in patients with different outcome.

Outcome	Outcome «A»		Outcome «F»	
Degree of shock	Frequency	%	Frequency	%
0	20	7,6	1	0,91
1	79	30,04	6	5,45
2	52	19,77	8	7,27
3	95	36,12	38	34,55
4	17	6,46	57	51,82

Source: *data processed by the authors*

As seen from the results shown in Table 9, in the case of a positive outcome, 57,41 % of the victims were characterized by a degree of shock from 0 to 2, and in the cases with fatal outcome more than half of the victims (51,82%) had the 4th degree of shock. At the same time in the group of victims with positive outcome 36,12 % had 3rd degree of shock, while in the group with fatal outcome this figure was 34,55 %, i.e., there is similar incidence in these two groups. At the same time, the use of nonparametric criterion (sign criterion and Wilcoxon criterion) revealed a significant statistical difference for samples, characterizing the degree of shock in patients with positive and fatal outcomes with $p < 0.01$.

To estimate the probability of the outcome for various categories of trauma we have developed a predictive model, based on the logistic relationship, represented by the following expression:

$$y = \frac{e^{c+c_1 \cdot x_1 + c_2 \cdot x_2 + \ldots + c_n \cdot x_n}}{1 + e^{c+c_1 \cdot x_1 + c_2 \cdot x_2 + \ldots + c_n \cdot x_n}}$$

where y is the estimate of the probability that the outcome will be positive, $c, c_1, c_{2,\ldots,} c_n$ are unknown parameters of the estimation model, to be estimated using the maximum likelihood method, and $x_1, x_2, \ldots, x_n$ represent a number of factors characterizing the condition of the victim, personal history, etc. Factors may be quantitative or qualitative values.

In the latter case, *dummy* variables, that take the value 1 if the sign (or symptom) is observed for the given victim, and 0 – otherwise, are used. The factorial indicators used in the models should be independent or have a low degree of correlation. In the case of strong correlation of factor indicators, distorted estimates of model parameters and incorrect signs can be obtained.

In this model, the value y ranges from 0 to 1; the closer the calculated value to 1, the greater the probability that the victim will survive.

Table 10 presents estimates of the parameters of the logit model for the prediction of the outcome for victims with various categories of trauma.

Table 10: Estimates of parameters of logit model for prediction of the outcome for victims with various categories of trauma.

Variable	Meaning of variable	Estimate of parameter (Coefficient)	Standard deviation	z-Statistic	p-level
C	Constant	1,524715	0,542393	2,811086	0,0049
D15	Polytrauma	-0,340150	0,529008	-0,642995	0,5202
D16	Abdominal trauma (AbdomTr)	0,194211	0,581121	0,334201	0,7382
D17	Chest trauma (ChestTr)	0,520494	0,559294	0,930627	0,3520
D18	Craniocerebral trauma (Cr-Cer.Tr)	0,710541	0,537810	1,321175	0,1864
D19	Pelvic trauma (PelvTr)	-0,037213	0,622768	-0,059754	0,9524
D20	Orthopedic trauma (OrthopTr)	0,057394	0,590155	0,097252	0,9225
D21	Spinal trauma (SpinTr)	-0,841292	0,986316	-0,852964	0,3937
D28	Trauma of lungs (TrL)	-1,168893	0,317405	-3,682658	0,0002
D29	Trauma of heart (TrH)	-1,471274	0,340561	-4,320146	0,0000
D30	Trauma of parenchymatous organs (TrParenh)	-0,031516	0,501797	-0,062807	0,9499
D31	Trauma of liver (TrLiv)	-0,571780	0,461612	-1,238660	0,2155
D32	Trauma of pancreas (TrPan)	-1,886609	0,514268	-3,668535	0,0002
D33	Trauma of hollow organs (TrHol)	0,049987	0,378534	0,132054	0,8949
D34	Trauma of bowel (TrBow)	-1,144548	0,529621	-2,161072	0,0307

Source: *data processed by the authors in Statistica*

Dummy variables, indicating the presence or absence of various types of trauma, were used as additional factor variables. Information about the outcome for a given victim with the indicated type of trauma was used as the dependent variable. The dependent variable took the value 1 in the case of a positive outcome and 0 in the case of a fatal outcome.

As seen from the values of the estimates, correct signs were obtained in most factorial indicators, while estimates of parameters are statistically significant at the level $p < 0.05$ for variables D28 (trauma of lung), D29 (trauma of heart), D32 (trauma of pancreas), D34 (trauma of bowel). Sufficiently large negative estimates of parameters, showing the influence of each factor on the decline of the probability of the victim's survival, were received for these factorial indicators.

The logit model which we have obtained has a high degree of accuracy in predicting positive outcomes. Thus, based on the *a posteriori* analysis, 92 % of cases in which victims survived were correctly recognized by the model.

Considering that abdominal trauma is the most common among all mechanisms of trauma [1,2,7,14,16], we constructed a predictive model for estimating the probability of a positive outcome in abdominal trauma and injury of certain organs of the abdominal cavity.

The results of the evaluation of parameter estimates for this model are shown in Table 11.

As seen from the results, we obtained parameter estimates with the correct signs which were statistically significant at the level $p < 0{,}05$ for most factorial indicators. It is confirmed analytically that the presence of peritonitis, and a high degree of shock severity significantly reduce the chances of survival. Also, the chance of survival reduces with increasing age and increasing value on the ISS scale.

The obtained parameter estimate for trauma of the pancreas is not statistically significant at 5%, because p-level is 8%, nevertheless this factor should be taken into account at the level $p < 0{,}1$. The estimates of the parameters for other factors (abdominal trauma, trauma of parenchymatous organs, trauma of bowel) are not significant in this model, nevertheless it is possible to explain as effect of multicollinearity of these injures and their synergic effect on the development of peritonitis and shock.

The logit model which we have obtained has a high accuracy in predicting positive outcomes. Thus, based on the *a posteriori* analysis, more than 90% cases of abdominal trauma, where victims survived, were correctly recognized by the model. Linear discriminant models can be used for the classification of possible outcomes.

Table 12 shows the results of the construction of linear discriminant functions for the classification of possible outcomes depending on the condition of the victim and the resuscitation measures undertaken.

Table 11: Estimates of logit model parameters predicting the outcome for victims with abdominal trauma.

Variable	Meaning of variable	Estimate of parameter (Coefficient)	Standard deviation	z-Statistic	p-level
C	Constant	7,536723	0,862621	8,737004	0,0000
AGE	Age	-0,057595	0,013014	-4,425768	0,0000
D16	Abdominal trauma (AbdomTr)	0,476250	0,432612	1,100870	0,2710
D30	Trauma of parenchymatous organs (TrParenh)	0,216656	0,616793	0,351261	0,7254
D31	Trauma of liver (TrLiv)	-0,203177	0,549646	-0,369651	0,7116
D32	Trauma of pancreas (TrPan)	-0,986243	0,570621	-1,728369	0,0839
D34	Trauma of bowel (TrBow)	-0,832464	0,570490	-1,459208	0,1445
D37	Peritonitis	-1,411723	0,553587	-2,550135	0,0108
ISS	Injury Severity Score	-0,071683	0,015300	-4,685142	0,0000
SHOCK_LEVEL	Degree of shock severity	-0,993547	0,173797	-5,716700	0,0000

Source: *data processed by the authors in Statistica*

Table 12: Estimates of model parameters of discriminant functions for prediction of outcome of a number of indicators, characterizing the condition of the victim and the resuscitation measures undertaken.

Variable (reference designation)	Meaning of variable	Outcome	
		A	F
		p=0,83871	p=0,16129
DL_IVL	Duration of artificial pulmonary ventilation (APV)	0,779429	1,535808
AD_KON_O	BP at the end of operation	-0,48866	-0,8649
T_D_GOSP	Time before hospitalization	-3,80992	-4,13625
V_KR_POT	Volume of hemorrhage	0,011747	0,003154
V_REINF	Volume of reinfusion	0,009094	0,018601
SK_VV_O	Speed of i/v infusion during the operation	0,978383	1,304658
AD_PER_O	BP before operation	0,90825	1,236515
MAX_AD_O	Maximal BP during operation	0,683466	0,850671
MIN_AD_O	Minimal BP during operation	-0,19844	-0,38035
AD_POST	BP at the arrival	0,964129	1,119812
T_D_REAN	Time before the beginning of resuscitation measures	-0,26222	-0,3428
Constant	Constant	-109,606	-129,253

Source: *data processed by the authors in Statistica*

The respective discriminant function has the following form for a positive outcome:

$$D(A) = -109{,}606 + 0{,}7794 \cdot DL\_IVL - 0{,}4886 \cdot AD\_KON\_O - 3{,}8099 \cdot T\_D\_GOSP +$$

$$+ 0{,}0117 \cdot V\_KR\_POT + 0{,}0091 \cdot V\_REINF + 0{,}9783 \cdot SK\_VV\_O + 0{,}9082 \cdot AD\_PER\_O +$$

$$+ 0{,}6834 \cdot MAX\_AD\_O - 0{,}1984 \cdot MIN\_AD\_O + 0{,}9641 \cdot AD\_POST - 0{,}2622 \cdot T\_D\_REAN$$

The respective discriminant function has the following form for a fatal outcome:

$$D(F) = -129{,}253 + 1{,}5358 \cdot DL\_IVL - 0{,}8649 \cdot AD\_KON\_O - 4{,}1362 \cdot T\_D\_GOSP +$$

$$+ 0{,}0031 \cdot V\_KR\_POT + 0{,}0186 \cdot V\_REINF + 1{,}3046 \cdot SK\_VV\_O + 1{,}2365 \cdot AD\_PER\_O +$$

$$+ 0{,}8506 \cdot MAX\_AD\_O - 0{,}3803 \cdot MIN\_AD\_O + 1{,}1198 \cdot AD\_POST - 0{,}3428 \cdot T\_D\_REAN$$

The value of each discriminant function is determined and then the highest value is selected for classification of the possible outcome. The most probable outcome will be where the relevant value of the discriminant function was the highest. The discriminant model which we have obtained is statistically robust, as evidenced by the values of Fisher's F-statistic ($F(11,19) = 5{,}3764$ at $p < 0{,}0007$), and has an acceptable value of Wilk's lambda equal to 0,243. The presented model has a high predictive accuracy. On the basis of *a posteriori* analysis using these discriminant functions, correct conclusions were drawn in 90% of cases when there was a positive outcome, and in 75% of cases when the outcome was fatal.

Thus, the mathematical apparatus allows the user to conduct a more accurate analysis of processes connected with the efficiency of resuscitation measures and with the serious or critical condition of the victim. Methods of mathematical statistics, such as the fitting of survival models for the prediction of outcomes, need to be applied more comprehensively in medical research, first of all in medical emergencies and in resuscitation.

The predictive model designed in this study can reasonably be used along with other qualitative and quantitative methods to determine the prognostic outcome in patients with severe trauma.

As different models have different predictive accuracy and require the provision of different information, it is necessary to use a sufficiently large number of techniques to refine the accuracy of predictions and to choose the right tactics of diagnosis and treatment. Thus, survival models also allow us to evaluate possible risks associated with the development of post-traumatic syndrome in patients discharged after severe injuries, which may pose a threat to the patient`s health or life in the future. Survival models permit the assessment of the possible risks of complications and of the dynamics of their occurrence according to the nature of the injury and the individual characteristics of the victims.

Considering the complexity of computational procedures for the use of certain techniques or scales, Ukraine needs to develop and implement in practice appropriate automated expert systems that can process large amounts of information about each victim, monitor treatment outcomes, and assess their effectiveness. At the same time, the powerful potential of modern statistical methods in medical and clinical research is not widely used in Ukraine, in contrast to the practice of leading Western centres, which have established analytical groups, professionally engaged in the collection and processing of data, and in the construction of predictive models and expert systems. According to this, Ukraine and other countries have a real need to develop native predictive models, which can be applied in cases of traffic accidents and other anthropogenic accidents, in order to assess the severity of trauma, estimate the probabilities of outcomes and analyze indicators such as the condition of the victims.

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Appendix

Table A.1: Descriptive statistics for mortality rates from road transport accidents (per 100 000).

Mean	Confid. -95.000%	Confid. +95.000%	Me-dian	Min	Max	Lower Quartile	Upper Quartile	Std. Dev.	Skew-ness	Kurto-sis
16,14	14,84	17,44	15,45	1,9	35,9	7,8	24,2	8,86	0,18	-1,13

Source: Source: data elaborated by authors in Statistica on the basis of information from https://en.wikipedia.org/wiki/List_of_countries_by_traffic-related_death_rate

Table A.2: Distribution of countries in the world according mortality rates from road transport accidents.

Quartile 1 [1,9;7,8)	Quartile 2 [7,8;15,45)	Quartile 3 [15,45;24,2)	Quartile 4 [24,2;35,9]
Andorra	Hungary	Afghanistan	Swaziland
Antigua and Barbuda	Albania	Algeria	Angola
Australia	Argentina	Armenia	Belize
Austria	Bahamas	Bolivia	Benin
Azerbaijan	Bangladesh	Bosnia and Herzegovina	Burkina Faso
Bahrain	Belarus	Botswana	Cameroon
Barbados	Bhutan	Brazil	Cape Verde
Belgium	Bulgaria	Cambodia	Central African Republic
Canada	Chile	Chad	Congo
Cuba	Costa Rica	China	Democratic Republic of the Congo
Cyprus	Croatia	Colombia	Djibouti
Czech Republic	Dominica	Cook Islands	Dominican Republic
Denmark	Egypt	Ecuador	Ethiopia
Estonia	Georgia	El Salvador	Gambia
Fiji	Greece	Eritrea	Ghana
Finland	Indonesia	Gabon	Guinea
France	Jamaica	Guatemala	Guinea-Bissau
Germany	Kyrgyzstan	Guyana	Jordan
Iceland	Laos	Honduras	Kenya
Ireland	Latvia	India	Lesotho
Israel	Lebanon	Iran	Liberia
Italy	Lithuania	Iraq	Libya
Japan	Mauritius	Ivory Coast	Madagascar
Kiribati	Mexico	Kazakhstan	Malawi
Luxembourg	Montenegro	Kuwait	Mali
North Macedonia	Nicaragua	Malaysia	Mauritania
Maldives	Pakistan	Mongolia	Mozambique
Malta	Panama	Morocco	Niger
Marshall Islands	Peru	Myanmar	Oman

Federated States of Micronesia	Philippines	Namibia	Rwanda
Netherlands	Poland	Nepal	São Tomé and Príncipe
New Zealand	Qatar	Nigeria	Saudi Arabia
Norway	Republic of Moldova	Papua New Guinea	Senegal
Palau	Romania	Paraguay	Sierra Leone
Portugal	Saint Vincent and the Grenadines	Russia	Somalia
San Marino	Seychelles	Saint Lucia	South Africa
Serbia	South Korea	Samoa	Sudan
Singapore	Taiwan	Solomon Islands	Tanzania
Slovakia	Trinidad and Tobago	Sri Lanka	Thailand
Slovenia	Turkey	Suriname	Togo
Spain	Turkmenistan	Tajikistan	Tunisia
Sweden	Ukraine	Timor-Leste	Uganda
Switzerland	United States	United Arab Emirates	Vietnam
Tonga	Uruguay	Vanuatu	Zambia
United Kingdom	Uzbekistan	Yemen	Zimbabwe

Source: data elaborated by authors in Statistica on the basis of information from https://en.wikipedia.org/wiki/List_of_countries_by_traffic-related_death_rate

Table A.3: Persons killed in road accidents by road user, 2011 (%, selected countries).

Country	Driver	Passenger	Pedestrian	Unknown
Belgium	72,6	14,3	12,9	0,1
Czech Republic	58,6	18,6	22,8	0,0
Denmark	68,6	16,4	15,0	0,0
Germany	70,5	14,2	15,3	0,0
Greece	62,5	18,0	19,5	0,0
Spain	62,7	18,9	18,4	0,0
France	69,7	17,2	13,1	0,0
Croatia	64,4	18,7	17,0	0,0
Cyprus	70,4	11,3	18,3	0,0
Latvia	45,3	21,2	33,5	0,0
Luxembourg	66,7	15,2	18,2	0,0
Hungary	57,7	22,9	19,4	0,0
Netherlands	77,5	10,3	11,9	0,4
Austria	68,3	15,1	16,6	0,0
Poland	46,4	20,0	33,6	0,0
Portugal	59,6	18,1	22,3	0,0
Romania	40,1	22,9	37,0	0,0
Slovenia	69,5	15,6	14,9	0,0
Finland	67,8	18,2	14,0	0,0
United Kingdom	60,5	15,8	23,8	0,0

Source: Eurostat (on-line data code: tran_sf_roadus)
Available at:
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Transport_accident_statistics&oldid=224104#Road_accident_statistics

In memory of our friend and colleague, professor of medicine Alexander Sinelnikov

On May 16, 2020 our dear friend, colleague and co-author, professor of medicine, famous pathologist Alexander Sinelnikov, passed away.

Alexander Yakovlevich Sinelnikov was born into a famous medical family: his grandfather, Rafail Davydovich Sinelnikov, a Soviet anatomist and medical scientist, worked under the guidance of academician V.P. Vorobyov.

From 1924 to November 1945, Rafail Sinelnikov was an assistant in the laboratory at the Mausoleum of V.I. Lenin. During the Great Patriotic War, he, along with B.I. Zbarsky, was responsible for the care of the body of V.I. Lenin. From 1937 he headed the Department of Anatomy of the 1st Kharkov Medical Institute. R.D. Sinelnikov, together with academician V. P. Vorobyov, prepared and published the five-volume Atlas of Human Anatomy (1938-1942), which remained for many years one of the most popular textbooks for higher medical educational institutions of the USSR and beyond.

Alexander Yakovlevich continued the family dynasty, graduated from the Kharkov Medical Institute, defended his PhD thesis and devoted his scientific research to the problems of pathological anatomy. Alexander Yakovlevich published a unique modern four-volume "Atlas of Human Anatomy", which includes original illustrations, radiographs and photographs of materials.

In recent years, Alexander Yakovlevich lived and worked in the United States, where he was engaged in scientific and teaching activities at the Department of Pathology, Lake Erie College of Medicine (LECOM), Bradenton FL, USA. We will always remember our colleague as a scientist, a wonderful teacher and a friend.