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Characteristics, Volume, and Severity of Injuries in Drivers of Modern Passenger Cars Who have been Injured as a Result of Road Traffic Accidents

Indiaminov S. I.*, Bakhtiyorov B. B.

Republican Scientific and Practical Center for Forensic Medical Examination under the Ministry of Health of the Republic of Uzbekistan, Tashkent, Uzbekistan

Abstract Globally, the incidence of trauma from road traffic accidents (RTAs) has shown a constant increasing trend and remains the leading cause of mortality and disability among nearly all age groups, predominantly affecting those of the most productive age, 18 to 60 years. **The aim of this report** was to identify the character, volume, severity, and peculiarities of injury formation in drivers of modern passenger cars who have been injured as a result of RTAs. Between 2020 and 2023, forensic medical examinations of the corpses of 119 drivers of the modern passenger car Chevrolet-Daewoo-UZ, who died in RTAs, were conducted. Among the deceased drivers, 116 were men and 3 were women aged between 19 and 69 years. **The study showed** that the most frequently damaged structures in drivers of modern passenger cars involved in RTAs were those of the chest and thoracic organs (84.8%), followed by those of the abdominal organs (78.1%) and those of the head and brain (67.2%) ($P \leq 0.001$). Fractures in the long tubular bones of the upper and lower limbs (44.0% of drivers of Lacetti and 30.3% of drivers of Nexia), vertebral-spinal injuries (22.0% of drivers of Lacetti and 11.5% of drivers of Nexia), and injuries to the retroperitoneal space organs (5.5% and 2.0%, respectively) were also common. **Thus**, despite the equipping of modern cars with safety devices and significant changes in the design of car interiors, drivers injured in RTAs still have a high severity and significant volume of combined and multiple traumas. The predominant injuries in drivers with modern in-car trauma include combined trauma to the chest, head, abdomen, and spine and fractures of limb bones, predominantly in the lower limbs.

Keywords Car

1. Introduction

Globally, trauma resulting from RTAs, which has a constant tendency to increase, remains the primary cause of death and disability among almost all age groups, especially in the most productive age range of 18-60 years. According to statistical data, "...approximately 50 million people worldwide suffer injuries of varying severity as a result of road accidents annually, and more than 1.2 million cases lead to fatalities..." and "...in Uzbekistan, in the eight months of 2023 alone, approximately 6,000 cases of road accidents were registered, resulting in 5,448 injuries, 1,415 of which were fatal" [World Health Organization. Global Status Report on Road Safety. October 28, 2021 WHO; Report information as of September 5, 2023, 13: 05. https://www.gazeta.uz].

Numerous scientific studies are being conducted worldwide to scientifically substantiate the mechanogenesis and pathogenesis of combined and multiple types of trauma, including the following priority directions: development of clinical-morphological classifications of combined (multiple) trauma and high-technology methods for early diagnosis, treatment, and rehabilitation of patients with polytrauma; establishment of the antemortem nature, timing of injuries, and degree of severity of the health damage caused; substantiation of the mechanogenesis and thanatogenesis of combined trauma; development of diagnostic and differential diagnostic criteria for various types of modern automotive trauma and preventive measures for trauma; establishment of the sequence of injuries in combined types of transport trauma; and diagnosis and differential diagnosis of injuries in drivers and passengers who have suffered in-car transport trauma by determining their location at the time of the RTA. [Fetisov V.A., Karavaev V.M., Burakova V.I., Meshcheryakova S.A., Tamberg D.K. 2020; Bychkov A.A. 2012; Curtin E, Langlois NE. Predicting Med Sci Law. 2007; Durbin DR, Jermakian JS, Kallan MJ, McCartt AT, Arbogast KB, Zonfrillo MR, Accid Anal Prev. 2015; Mitchell RJ, Bambach MR, Toson B. Accid Anal Prev. 2015].

In-car automotive trauma is one of the most frequently observed types of road traffic trauma. According to the

* Corresponding author:
sayit.indiaminov@bk.ru (Indiaminov S. I.)
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literature, this type of injury accounts for 28-30% to 33-35% of all types of automotive trauma. Modern automobiles have significantly improved in terms of interior design and are equipped with active and passive safety features, although the speed of modern passenger cars is considerably high. Consequently, with any type of automotive trauma, particularly during collisions of modern passenger cars with other vehicles (obstacles) or rollovers, the volume of injuries to drivers and passengers related to inertial body movements can exceed that associated with the cabins of passenger cars manufactured in the previous century [Fetisov V.A., Gusarov A.A., Smirenin S.A. 2016; Sarkisyan B.A., Panykov I.V. 2014; Shevchenko K.V., Borodulin D.V. 2019; Bychkov A.A., Dubrovin I.A., Gerasimov A.N., Grukhovsky S.V., Mosoyan A.S. 2018].

These circumstances necessitate a detailed analysis and study of the medical-social and forensic medical aspects of contemporary automotive trauma, with the development of diagnostic methods to substantiate the mechanism of injuries in specific types of modern automotive trauma, particularly in in-car trauma, as the most frequent type of RTA [Kovalev A.V., Momat D.V., Samokhodskaya O.V., Zabrodsky Y.D. 2020]. The results obtained can serve as a basis for determining rational methods for treating patients with combined and multiple polytrauma procedures.

Objective. **The aim of this report** was to identify the characteristics, volume, severity, and peculiarities of injury formation in drivers of modern passenger cars who have been injured as a result of road traffic accidents.

2. Materials and Methods

At the bases of the Samarkand, Navoi, and Tashkent regional branches of the Republican Scientific and Practical Center for Forensic Medical Examination of the Ministry of Health of Uzbekistan, between 2020 and 2023, forensic medical examinations of the bodies of 119 drivers of the modern passenger car Chevrolet-Daewoo-uz, who died in RTAs, were conducted. Among the deceased drivers, 116 were men and 3 were women aged between 19 and 69 years. In 2 patients, the drivers were under the influence of alcohol at the time of the RTA, with blood ethanol concentrations of 0.5 and 1.5 per mille. At the time of the RTAs, the drivers were behind the wheel of a Nexia, Chevrolet-Daewoo-uz., (69) and a Lacetti, Chevrolet-Daewoo-uz., (50). The circumstances of the RTAs were collisions of cars with other vehicles (71), collisions of cars with various stationary obstacles (40) and rollovers of cars (8).

During the forensic medical examination, particular attention was given to the character, location, and peculiarities of the marks on clothing and shoes, as well as the character, localization, and volume of damage to organs and tissues. The systematization of combined and multiple traumas was carried out in accordance with known unified anatomical-clinical classifications of polytrauma. This also took into account modern clinical-morphological classifications of craniocerebral trauma (CCT), fractures of bones, and internal organs. The materials used for the preliminary inquiry and investigation, protocols for inspecting the accident site and the body at the time of its discovery, data from the vehicle inspection, and results from forensic-technical experts and testimonies of witnesses to the incident, were also studied. The obtained data were entered into coded registration cards for statistical analysis. Statistical analysis was carried out within the framework of variation statistics with the determination of the reliability criterion of injury indicators (t), their minimum error (m), and the reliability of differences (p) between the indicators:

3. Results and Discussion

The study showed that the most frequently damaged structures in drivers of both car brands involved in RTAs were those of the chest and thoracic organs (84.8%), followed by those of the abdominal organs (78.1%) and those of the head and brain (67.2%) ($P \leq 0.001$). The occurrence of vertebral-spinal injuries (22.0% in drivers of Lacetti and 11.5% in drivers of Nexia), injuries to the organs of the retroperitoneal space (5.5 and 2.0%, respectively), and the formation of fractures in the long tubular bones of the upper and lower limbs (44.0% in drivers of Lacetti and 30.3% in drivers of Nexia) were also common. Lesions of the bone structures of the facial section (8.0% and 12.0%) and fractures of the pelvic bones (10.0% and 33.3%) in drivers of both brands were also relatively rare compared to injuries of other structures. (Table No. 1.)

The analysis of the morphological features of head and facial injuries showed that in Chevrolet-Daewoo-uz drivers of passenger cars, contusions, abrasions, and bruised wounds were often observed in the right temporal, parieto-temporal area; on the eyelids of the right eye; in the forehead area; on the lower lip and chin; on the right cheek; in the fronto-parieto-temporal area; and in the nose area. Fractures of the vault and base of the skull in the deceased drivers of the Lacetti car were found in 55.2% of the HELLP syndrome patients; these patients often had comminuted, multifragmented, and depressed-comminuted fractures, which were mainly located in the frontal-parietal and temporal regions on the right ($P \leq 0.003$). Multifragmented fractures were accompanied by destruction of brain tissue. Linear fractures of the vault and base of the skull were accompanied by brain contusions with subdural hemorrhages and in the brain tissue itself.

Fractures of the vault and base of the skull in Nexia drivers were noted in 63.5% of the patients with injuries to the head structure and facial section. In some patients, these fractures had a comminuted and multifragmented nature with predominant localization in the frontal-parietal and temporal bones on both the right and left sides, and in some patients, these fractures were accompanied by destruction of brain tissue ($P \leq 0.005$). In most cases, the fractures of the vault and base of the skull had linear shapes and were accompanied by severe brain contusion. Among the bone structures of the

facial sections of Nexia car drivers, there were fractures of the nasal bone, lower jaw, and zygomatic bones.

Table 1. Frequency of damage to certain parts of the body of drivers killed in road accidents

No	Anatomical parts of the body	Injuries to certain parts of the body				Total	
		Drivers of Lacetti (n=50)		Drivers of Nexia (n=69)			
		Abs.	%	Abs.	%	Abs.	%
1.	Head	34±0,2	68,0±0,7	46±0,3	66,6±0,9	80±0,03	67,2±0,6
2.	Facial region	4±0,03	8,0±0,06	6±0,02	12 ±0,08	9±0,01	7,5±0,04
3.	Thorax	45±0,4	90,0±0,3	56±0,8	81,1±0,5	101±1,1	84,8±0,7
4.	Spine and spinal cord	11±0,07	22,0±0,1	8±0,06	11,5±0,07	19±0,08	15,9±0,04
5.	Abdomen	36±0,8	72,0±0,4	57±0,7	82,6±0,06	93±0,9	78,1±0,4
6.	Retroperitoneal space	10±0,06	20,0±0,1	4±0,03	5,7±0,04	14±0,06	11,7±0,07
7.	Pelvis	5±0,05	10,0±0,02	2±0,1	33,3±0,07	7±0,04	5,8±0,04
8.	Fractures of the bones of the upper extremities:	8, out of:	16,0%±	10, out of:	14,4±0,09	18±0,08	15,1±0,08
		-Right -Left -Both	2±0,01 4±0,02 2±0,01	Right -Left -Both	2±0,01 6±0,03 2±0,02		
9.	Fractures of the bones of the lower extremities:	14, out of:	28,0±0,5	11, out of:	15,9±0,04	25±0,05	21,0±0,04
		-Right -Left -Both	8±0,06 4±0,02 2±0,01	-Right -Left -Both	2±0,01 7±0,05 2±0,01		
Total			**50**±0,4		**69**±0,8	**119**±0,03	**100**±0,04

* "abs." refers to the absolute number of cases.

Table 2. Data on the incidence of injuries to the structure of the chest and organs of the thoracic cavity in the deceased drivers of Chevrolet-Daewoo-UZ passenger cars

A. Drivers of a Lacetti car (n=45 with chest injuries).

No	Features of structural injuries	Location of injuries	Abs.	%
1.	Bruises	• on the anterior wall of the chest • Localizations are not specified • in the area of the left scapulae • Left side of the chest	2±0,02 8±0,07 1±0,01 2±0,01	
		Total	13±0,09	28,8±0,07
2.	Bruises, hematomas	• on the left side of the chest	1±0,01	
		Total	1±0,01	2,2±0,01
3	Sternum fractures	• Localizations are not specified • Manubrium • Body	5±0,03 1±0,01 1±0,01	
			7±0,03	15,5±0,09
4.	Clavicle fractures	• Left • Right	1±0,01 1±0,01	
			2±0,03	4,4±0,03
5.	Rib fractures:	• Right • Left • Bilateral	10±0,05 7±0,03 15±0,09	
		Total	33±0,6	73,3±0,8
6.	Lung ruptures:	• Right • Left • Both	3±0,04 1±0,01 10±0,07	
		Total	14±0,08	31,1±0,4
7.	Ruptures of the heart and pericardium, aorta and pulmonary artery		17±0,09	37,7±0,2

No	Features of structural injuries	Location of injuries	Abs.	%
8.	Ruptures of diaphragm		3±0,02	6,6±0,04
9.	Hemorrhages in the roots and tissue of the lungs and in the mediastinal tissues	Total	45±0,6	100±0,01

B. Drivers of Nexia passenger cars

No	Features of structural injuries	Location of injuries	Abs	%
1.	Bruises	• anterior chest wall • in the axillary region • not specified	3±0,02 1±0,01 1±0,01	
			5±0,07	8,9±0,03
2.	Bruises, hematomas	• along the lateral and posterior walls of the chest • not specified	1±0,01 2±0,02	
			3±0,04	5,3±±0,06
3	Contusion wounds	• Localizations are not specified	2±0,01	3,5±0,06
4.	Sternum fractures	• Body • Not specified	4±0,03 5±0,04	
			9±0,7	16,07±0,1
5.	Clavicle fractures	• Left clavicle • right clavicle • Both	2±0,02 6±0,02 1±0,01	
			9±0,1	16,07±0,2
6.	Scapula fractures	0		
7.	Rib fractures	• right • left • bilaterally	6±0,07 8±0,04 24±0,3	
		Total	38±0, 4	67,8±0,8
8.	Lung ruptures:	• Right • Left • Both	2±0,02 3±0,04 2±0,02	
		Total	7±0,09	12,5±0,7
9.	Heart ruptures	• left ventricle	4±0,06	7,14±0,01
10.	Ruptures of the aorta and pulmonary artery	• Thoracic region • Pulmonary artery	1±0,01 1±0,01	
		Total	2±0,01	3,5±0,02
11	Hemorrhages in the roots and tissue of the lungs and in the mediastinal tissues	Total	56±0,7	100±0,1

* "abs." refers to the absolute number of cases.

A quantitative analysis of the frequency of chest structure injury was also conducted (Table No. 2 A and B).

As shown in Table No. 2 A and B, injuries to the skin of the chest wall were not noted in patients with chest injuries caused by Lacetti or Nexia passenger cars. The most commonly identified injuries in drivers of both car brands were rib fractures (73.3% and 67.8%, respectively), with bilateral fractures along multiple anatomical lines prevailing. Additionally, ruptures of both lung tissues were more frequently observed ($P \leq 0.001$). Ruptures of the heart, pericardium, thoracic aorta, and pulmonary artery were also often noted. In all cases of chest organ injury in drivers of both brands, contusions of the lungs were determined as hemorrhages in the area of their roots and tissue. Rib fractures and organ ruptures are usually accompanied by manifestations of hemo- and pneumothorax, often bilaterally, which, in addition to causing trauma to other body parts, can either directly cause death or contribute to the occurrence of death in drivers in the early period of combined trauma. Sternal fractures were noted in 15.5 and 16.07% of the patients, and clavicle fractures were more common in Nexia drivers (16.07%), often in the right clavicle, and in Lacetti drivers (4.4%).

Spinal and spinal cord injuries (SSCIs) were noted in 11 (out of 50) drivers of the Lasetti nail and in 8 (out of 69) drivers of the Nexia. The SSCIs in drivers were most often characterized by avulsion fractures (8 out of 14), mainly in the cervical region (5 out of 38); C1-C2 or C5-C6 ($P \leq 0.001$); or in combination with avulsion fractures of the thoracic region (3 out of 38). In some cases, cervical-occipital trauma (COT) was observed in drivers of the Lacetti car, and in 3 deceased drivers, fractures of the body, either C2(1) or the

spinous processes of Th6 to 12 (1), were noted. Moreover, for Nexia drivers, 1.2-SSCIs were noted in 8 out of 69 observations; more often (4 out of 8) were characterized by COT and avulsion fractures (3) at the C3-4-C5-6 and Th2-3 levels, and in one case, a whiplash fracture of C2 was noted. In all the cases, the SSCIs of drivers of both brands were accompanied by avulsions or contusions and bruising of the spinal cord at the level of fracture, which was the direct cause of death at the scene of the injury.

Injuries to the structure and organs of the abdomen in drivers of the modern passenger car Chevrolet-Daewoo-UZ were observed quite often—in drivers of the Lasetti car, 36 died out of 50 observations (70.2%), and in drivers of the Nexia car, 57 out of 69 observations (80.2%) were observed ($P \leq 0.001$). Among the deceased drivers of both car brands, hemorrhages in the ligaments and tissues of internal organs (17 and 38, respectively) were most often noted, followed by ruptures of liver parenchyma (mainly the large lobe) in combination with hemorrhages in organ ligaments (15 in Nexia drivers and 8 in Lacetti drivers) and simultaneous ruptures of liver and spleen parenchyma (7 in Lacetti drivers and 2 in Nexia drivers). In some cases, there were also isolated ruptures of the spleen (3 and 1, respectively), as well as ruptures of the mesentery of the intestine (1) or combined ruptures of the liver and pancreas (1) with massive hemorrhages in the ligaments and soft tissues of the abdominal cavity organs. All internal organ ruptures were accompanied by internal bleeding (up to 2 liters), which, in addition to injuries to other parts of the body, either caused or contributed to the death of the victims in the early period of combined trauma ($P \leq 0.003$).

Hemorrhages in the perirenal fascia and subcapsular hemorrhages in the kidneys (9 and 8, respectively) were noted from the structures of the retroperitoneal space organs of deceased drivers, and in some cases, both kidneys were ruptured with massive hemorrhages in the perirenal fascia. In deceased drivers, injuries to the structure and organs of the pelvis, compared to the frequency of injuries to the structures of the head, chest, spine, and abdomen, were observed relatively rarely (5 out of 50 and 69 observations). Fractures of the pubic and ischial bones and abrasions and bruises on the skin in the zone of fractures with hemorrhages in the soft tissues and muscles of the small pelvis were noted. Injuries in the area of the external genitalia, as well as the perineum and organs of the pelvic cavity, were not noted.

In drivers of both Lacetti and Nexia brand passenger vehicles, limb injuries were identified in the form of abrasions, contusions (hemorrhages), bruised wounds, and fractures of the bones of the upper and lower limbs, localized on both the right and left sides. Fractures in the limbs were noted in the diaphysis of the humeral bones, the bones of the forearms, the nail phalanx of the left hand, the femoral bones, the right patella, and the bones of both the right and left tibia; these fractures were often accompanied by bruised wounds in the area of fractures and displacement of the fracture edges. In the Lacetti drivers, fractures were predominantly observed in the lower limbs (13 out of 20), revealing diaphyseal fractures of the femoral and tibial bones on both the right and left sides, as well as bilateral femoral fractures. Fractures of the bones of the left forearm (4) or both humeral bones (2) and, in some cases, fractures of the nail phalanx of the thumb of the left hand (4) were frequently identified in this group of drivers. Cases of right patella fractures were also reported. Among Nexia drivers, fractures were more prevalent in the upper limbs (14 out of 19), with diaphyseal fractures of both humerus bones (5), the left forearm (4), and the left humerus (2) frequently noted. Fractures of the humerus and forearm bones on the right were reported in isolated cases. Moreover, Nexia drivers more commonly exhibited diaphyseal fractures of the left femoral bone (3), and single cases of fractures of the right femoral and left tibial bones were identified.

The literature on the characteristics and morphological features of injuries resulting from this type of automotive trauma is quite diverse. Most studies conducted in this area have been devoted to examining the nature and mechanism of injuries to individual body parts or structures, both for drivers and passengers. There is a near absence of data on the characteristics and peculiarities of injuries sustained in in-car automotive trauma involving Chevrolet-Daewoo-UZ passenger vehicles manufactured in Uzbekistan.

The mechanism of injury occurrence for drivers and passengers inside the cabin during collisions is conditioned by the phenomenon of body inertia (A.A. Solokhin, 1968). Typically, as a vehicle commences movement, the bodies of individuals within the cabin are thrown backward, with the deviation being greater as the vehicle transitions more rapidly from a stationary state into motion. Upon deceleration of the vehicle or sudden stop, occupants lean forward in accordance with the vehicle's motion, resulting in contact between body regions and the vehicle's interior parts (1st phase). The abrupt and sudden stop of the vehicle during collisions leads not only to the body leaning but also to it being propelled forward and upward (2nd phase). In this process, various parts of the front surface of the body, particularly the front seat passenger (FSP), collide with the components and mechanisms situated at the front of the cabin. In both phases, so-called contact (specific) and characteristic injuries may arise. The character of injuries is also influenced by the displacement (deformation) of individual cabin parts, such as the backward displacement of the steering wheel frequently observed in frontal collisions. In addition to contact and characteristic injuries, victims also sustain injuries associated with shaking, counterimpact, and compression of the body by the inwardly shifted deformed parts of the vehicle's interior—the 3rd phase (A.A. Solokhin, 1968).

Researchers from Norway, Jan Mario Breen et al. (2021), conducted an analysis of the characteristics and localization of injuries among 284 drivers, 80 front seat passengers (FSPs), and 37 rear seat passengers (RSPs), of which 67.3% perished in frontal collisions, 13.7% in side collisions, and 13.5% in vehicle rollovers, with 5.5% in combined collisions. Among the combined trauma cases, head injuries were the predominant cause of injury in all the victims (63.6%),

followed by chest cage injuries (61.6%). Abdominal organ injuries were identified in 27.4% of the victims, while neck injuries were present in 10.7% of the fatalities. In all the passengers, head and neck injuries resulted from contact collisions with the interior of the cabin. Heart and spleen injuries were less common in FSPs than in drivers. Fractures of the bones of the lower extremities occurred more frequently in these patients than in passengers. Moreover, all the plants exhibited abrasion marks on the skin from the safety belts. The authors also discovered that, for frontal impacts, the most common cause of death was injury to multiple regions (48.5%, 131/270), followed by isolated head injury (27.8%, 75/270), chest cage (19.3%, 52/270), abdominal trauma (3.0%, 8/270), and neck (1.5%, 4/270) injury. Among the side impacts, the most prevalent cause of death was isolated head injury (38.2%, 21/55), followed by injuries to multiple regions (34.5%, 19/55), isolated chest cage injuries (23.6%, 13/55), and neck injuries (3.6%, 2/55). In cases of vehicle rollover, the most common cause of death was isolated head injury (61.1%, 33/54), followed by multiple injuries (24.1%, 13/54) and isolated chest cage injuries (14.8%, 8/54) [Jan Mario Breen, Paul Axel Naess, Christine Gaarder, and Arne Stray-Pedersen. Medicine and Pathology 2021. p.235–246].

Our research results have shown that under contemporary conditions, injuries arising from in-car automotive trauma are characterized by a high degree of polymorphism, most often involving a lack of specific and characteristic injuries, as well as the emergence of new, previously unknown types of trauma. These circumstances are associated with significant alterations in body structure, the cabin interior, the presence of a complex of safety protection means, and the increased speed of movement of modern vehicles.

4. Conclusions

1. Despite modern vehicles being equipped with safety features and significant changes in cabin design, drivers involved in road traffic accidents (RTAs) continue to sustain high severity and a substantial volume of combined and multiple traumas. In contemporary in-car automotive trauma among drivers, combined injuries of the chest, head, abdomen, and spine and the formation of limb fractures, predominantly in the lower limbs, prevail;
2. The reduced elasticity and significant smoothness of interior cabin details, along with the presence of passive safety devices in modern passenger cars, contribute to the rarity of forming so-called "specific" injuries, such as steering column imprints on the chest skin and a decreased frequency of lacerations on the face and neck, as well as the insignificance of skin injuries on the anterior-lateral surfaces of the torso and damage to clothing and footwear in all phases of trauma;
3. The formation of injuries to the head structure and its facial section in drivers is caused by the 1st and 2nd phases of trauma, while chest structure injuries, in particular the formation of bilateral rib fractures along the anterior and lateral anatomical lines, are mainly due to the 3rd and partly 1st phases, i.e., compression of the chest by severely deformed cabin parts due to the reduced elasticity of interior details.
4. The mechanism of formation of extra-articular, periarticular, and diaphyseal fractures of limb bones, often bilateral, is more likely conditioned by the 1st and 3rd phases of trauma. Injuries to pelvic structures most often occur in the 3rd phase of RTAs. Abdominal structure injury most often occurs in the 1st and 2nd phases.
5. More characteristic of drivers is the formation of vertebral-spinal cord injuries, mainly in the form of avulsion fractures, with predominant trauma to the cervical spine, particularly in the form of cervical-occipital trauma and whiplash fractures caused by sharp flexion-extension movements of the torso in the 1st and 2nd phases of RTAs; these injuries are rarely observed or absent in drivers and FSPs of older car models.
6. The data provided can be considered in the process of forensic medical diagnosis of automotive trauma, as well as in the process of providing medical assistance to victims.

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