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Forensic characteristics of chest injuries among subjects who died in road traffic accidents

Forenzičke karakteristike povreda grudnog koša kod osoba poginulih u saobraćajnim nesrećama

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Abstract

Background/Aim. In road traffic accidents, chest injuries are a critical factor since death usually occurs as a result of injuries to the heart and lungs, flail chest, pneumothorax, exsanguination, etc. The aim of this study was to analyze the most vulnerable subjects in road accidents, as well as the most frequent and most significant types of chest injuries sustained by different categories of subjects, and to examine the relevance of certain injuries or factors to outliving the injuries. **Methods.** The autopsy, the retrospective, and the cross-sectional study were performed at the Clinical Centre of Kragujevac, Department of Forensic Medicine and Toxicology. The study included all participants in road traffic accidents on the territory of Kragujevac and the surrounding area who died from the injuries sustained from the accidents or due to complications of the injuries during the period from 2001 to 2016. The subjects were divided into the following groups: pedestrians, motor vehicle drivers, front-seat passengers, back-seat passengers, bicyclists, motorcyclists, and tractor drivers. The occurrence of injuries in three regions of the body (chest, head, and abdomen) was analyzed in all the subjects. **Results.** The study included 525 subjects who died due to the injuries sustained in traffic accidents, which makes up to 38.4% of the total number of 1,366 autopsy cases covered by the study period. The average age of the subjects was 52 ± 19 years. The study sample consisted of 391 (74.5%) men and 134 (25.5%) women. The most vulnerable subjects were pedestrians (220, i.e. 41.9%), followed by motor vehicle drivers (98, i.e. 18.7%), front-seat passengers (79, i.e. 15%), motorcyclists (39, i.e. 7.4%), bicyclists (38, i.e. 7.2%), back-seat passengers (29, i.e. 5.5%) and tractor drivers (22, i.e. 4.2%). Chest injuries were identified in 408 subjects (77.7%), while the most frequent type of injury was rib fracture, observed in two-thirds of the sample. Out of the total number, 291 (55.4%) subjects died at the scene of the accident or on their way to the hospital, while 234 (44.6%) of them outlived injuries for a certain period of time. Drivers exhibited the highest risk of dying at the scene, while bicyclists outlived their injuries more frequently. **Conclusion.** Chest injuries are very common in subjects who died at the scene of the road traffic accident.

Key words:
accidents, traffic; thoracic injuries; autopsy; cause of death.

Apstrakt

Uvod/Cilj. Povrede grudnog koša su značajne u saobraćajnom traumatizmu jer su čest uzrok smrti zbog povreda vitalnih organa – srca i pluća, torakalnog kapka, pneumotoraksa, povreda velikih krvnih sudova itd. Cilj ove studije bio je analiza vulnerabilnosti različitih učesnika u saobraćajnim nezgodama, utvrđivanje najučestalijih i najznačajnijih povreda grudnog koša kod različitih učesnika, kao i da se ispita značaj pojedinih povreda ili faktora za nadživljavanje povreda. **Metode.** Urađena je retrospektivna, autopsijska, studija preseka na materijalu Službe za sudsku medicinu i toksikologiju Kliničkog centra Kragujevac. U studiju su bili uključeni svi učesnici saobraćajnih nezgoda koji su umrli od zadobijenih povreda ili njihovih komplikacija na teritoriji grada Kragujevca sa okolinom, u periodu od 2001. do 2016. godine. Učesnici su bili podeljeni u sledeće grupe: pešaci, vozači motornih vozila, suvozači, putnici u vozilu, biciklisti, motociklisti i vozači traktora. Kod svih učesnika je analizirano prisustvo regionalnih povreda (grudnog koša, glave i abdomena). **Rezultati.** Studijom je bilo obuhvaćeno 525 učesnika čija je smrt bila posledica saobraćajne nezgode, što čini 38,4% od ukupnog broja obdukcija (1 366). Prosečna starost učesnika iznosila je 52 ± 19 godina. Muškaraca je bilo 391 (74,5%), a žena 134 (25,5%). Najvulnerabilniji učesnici su bili pešaci (220 ili 41,9%), vozači motornih vozila (98 ili 18,7%), suvozači (79 ili 15%), motociklisti (39 ili 7,4%), biciklisti (38 ili 7,2%), putnici (29 ili 5,5%) i vozači traktora (22 ili 4,2%). Povreda nekog dela grudnog koša je bila prisutna kod 408 (77,7%) učesnika, a najučestalija povreda je bila prelom nekog rebra, koja je evidentirana kod dve

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trećine učesnika. Od ukupnog broja, 291 (55,4%) učesnik je stradao na licu mesta ili na putu do odgovarajuće zdravstvene ustanove, dok je 234 (44,6%) učesnika nadživelo povrede neko vreme. Vozači su imali veću šansu da umru na licu mesta, dok su biciklisti češće nadživljavali povrede. **Zaključak.** Povrede grudnog koša su veoma česte u slučajevima smrtnog ishoda na licu mesta u saobraćajnim nezgodama.

Ključne reči:
udesi, saobraćajni; toraks, povrede; autopsija; smrt, uzrok.

Introduction

Out of all causes of death on the global scale, road traffic trauma is currently ranked ninth, albeit with a tendency to grow [1]. It is estimated that in 2030 it might come to be the fifth leading cause of death in the world, with 2.4 million deceased per year [1]. In road traffic accidents (RTAs), 1.25 million people die every year, which is more than 3,000 death instances per day [1]. The World Health Organization (WHO) has identified pedestrians, bicyclists, and motorcyclists as the most vulnerable categories of participants in RTAs, given the increased likelihood of sustaining a serious injury in accidents compared to drivers of motorized vehicles and passengers inside [1].

Blunt chest trauma (BCT) makes up 10–15% of all injuries and is identified as the main cause of death in approximately 25% of the subjects, while in approximately another 25% of instances, it is the contributing factor of deathly outcomes [2, 3]. In RTAs, chest injuries are the most numerous ones and are observed in approximately 60–80% of the instances [4–6], while in terms of causes of death, these injuries are found in approximately 15% of the casualties [3]. The most frequently injured are men in their 40s [5, 7].

RTA injuries to the chest remain a significant cause of morbidity and mortality. In the majority of RTAs, injuries to the chest are combined with the trauma of other regions of the body, such being the head or abdomen [5]. A rib fracture is one of the most common BCTs [5, 8]. Studies have reported that as the number of rib fractures increases, the number of complications increases, too, as well as mortality rates [8, 9], which is particularly pronounced in the elderly population [10]. Deceleration thoracic injuries are of great relevance (traumatic aortic transection, flail chest, myocardial contusion), most commonly occurring in motor vehicle collisions, and are classified as life-threatening injuries [11].

There are merely a few studies dealing with the frequency and the consequences of chest injuries in RTAs on the territory of the Republic of Serbia. A study conducted between 1973–1988 on the territory of Serbia concluded that chest injuries were observed in 62% of subjects involved in RTAs [12]. Thirty years later, RTAs remain the most common cause of chest injuries on the territory of Serbia (approximately 64%) [5]. Nikolić [13] and Nikolić et al. [14] demonstrated that chest organ injuries are most frequently concomitant RTAs and that there is a high probability that the fatally injured one is the motor vehicle driver, with a number of concomitant injuries of the thoracic aorta, heart, and pericardium, as well as with fractured thoracic cage bones.

Daskal et al. [15] proved that severe chest injuries were most common in front-seat passengers when compared to drivers and other passengers in the vehicle.

The aim of this study was to analyze the most vulnerable RTA participants, the frequency and types of chest injuries among different subjects, as well as to examine the relevance of certain specific chest injuries and factors in outliving the injuries.

Methods

The epidemiological (observational) analytical, retrospective and cross-sectional autopsy study was conducted at the Clinical Centre of Kragujevac, Department of Forensic Medicine and Toxicology, for sixteen years (between 2001 and 2016). The study included 525 RTA subjects (38.4% of 1,366) who died from sustained injuries or complications of the injuries on the territory of Kragujevac and the surrounding area. The subjects were included in the study according to the police reports, requests for forensic autopsy obtained from competent courts or prosecutions, or, in rare instances, based on retrospectively acquired hetero-anamnestic information. The data on the sustained injuries were obtained by analyzing the autopsy records, as well as the available medical documentation. The study did not include children under 14 years of age and subjects shorter than 150 cm.

Subjects were analyzed in terms of gender, age, and type of involvement in traffic accidents. The frequency of accidents was observed depending on the month of the year and the day of the week. According to their type of involvement in RTAs, all subjects were classified into the following groups: pedestrians, motor vehicle drivers, front-seat passengers, back-seat passengers, bicyclists, motorcyclists, and tractor drivers. Chest injuries were classified into the following groups: bone fractures of the chest (sternum, thoracic spine, unilateral or bilateral rib fractures), lung injuries (unilateral or bilateral: contusions, lacerations, disruptions), cardiac injuries (rupture of the pericardium, myocardial rupture, contusion, cardiac tamponade), aortic injuries (haematoma of adventitia of the aorta, aortic rupture), pneumothorax (unilateral or bilateral) and haemothorax. In addition, the analysis included the simultaneous occurrence of chest injuries and head or abdominal trauma. When considering the outliving period, the subjects were divided into two categories: subjects who died at the scene of the accident and those who outlived their injuries for a certain period of time.

Statistical Package for Social Sciences – SPSS for Windows, Version 20 (SPSS Inc. Chicago, IL) was used for data processing. All numerical variables were tested with the Kolmogorov-Smirnov and Shapiro-Wilks tests for normal distribution as criteria for further implementation of parametric methods. According to the data distribution, appropriate descriptive statistics were employed (mean values with standard deviation or median with interquartile range – IQR). To estimate the differences between variables that exhibited parametric distribution, the Student's *t*-test was used. The Pearson's chi-squared test (with Yates correction) and Kruskal-Wallis test were applied in variables that showed a nonparametric distribution. The analysis of the connection of dichotomous dependent variables (immediate death *versus* death after a period of outliving) and observational independent variables (injuries of certain body parts) was carried out by binary logistic regression. The results were presented as crude odds ratio (OR) with a 95% confidence interval (CI). After applying corrections for the influence of other independent and confounding variables, the acquired data were expressed as adjusted OR with a 95% CI. The p-value of 0.05 has been considered significant.

This study was conducted with the approval of the Ethics Committee of the Clinical Centre of Kragujevac (18/10/2016, No 01/13221).

Results

The study included 525 subjects, whose average age was 52.4 ± 19.4 years (ranging from 16 to 92 years). There were 391 (74.5%) men, aged 51.3 ± 19.6 years (ranging from 16 to 92 years), and 134 (25.5%) women, aged 55.8 ± 18.5 years (ranging from 16 to 84 years). The ratio of male and female subjects was approximately 3:1 (χ^2 = 125.808; df = 1; p = 0.000). On average, women were older than men (t test = -2.370; p = 0.019), which has been shown in all age groups (χ^2 = 8.735; df = 3; p = 0.033). A detailed overview of the results is provided in Table 1.

Among all the different categories of subjects, tractor drivers were the oldest (Kruskal-Wallis test = 100.34; df 7; p = 0.000). In addition, tractor drivers were the subjects with the highest percentage of identified chest injuries. The distribution of subjects according to RTA participation, their age, and occurrence of chest injuries is provided in Table 2.

Depending on the month of the year, the largest number of fatal RTAs was recorded in September (63, i.e. 12%), followed by August and October (60, i.e. 11.4%), while the fewest accidents took place in March (20, i.e. 3.8%) and February (25, i.e. 4.8%) (χ^2 = 47.274; df = 11; p = 0.000). When observing the days of the week, the highest number of fatal RTAs was recorded on Wednesdays (92, i.e. 18%), followed by Fridays and Sundays (85, i.e. 16%), while the fewest such accidents took place on Mondays (47, i.e. 9%) (χ^2 = 20.853; df = 6; p = 0.002).

In the study sample, chest injuries were identified in 408 (77.7%) out of 525 subjects, followed by head injuries (skull fractures or intracranial bleeding), which were observed in 339 (64.6%) out of 525 subjects. Abdominal injuries were found in 201 (38.3%) out of 525 subjects. Almost half of the subjects (241 out of 525, i.e. 45.9%) suffered from concomitant chest and head injuries, while one-third of them (188 out of 525, i.e. 35.8%) sustained concomitant chest and abdomen injuries. Simultaneous occurrence of chest, head and abdominal injury was identified in 103 out of 525 (19.6%) instances (χ^2 = 193.830; df = 1; p = 0.000).

Table 1

The distribution of road traffic accidents (RTA) subjects by age ranges and sex

Age ranges (years)	Men n (%)	Women n (%)	Total n (%)
16–35	97 (24.8)	21 (15.7)	118 (22.5)
36–50	76 (19.4)	19 (14.2)	95 (18.1)
51–65	104 (26.6)	44 (32.8)	148 (28.2)
> 65	114 (19.2)	50 (37.3)	164 (31.2)
Total	391 (100)	134 (100)	525 (100)

Table 2

The distribution, age, and presence of chest injuries according to types of road traffic accidents (RTAs) participation

RTA participants	Total number (%)	Age (years), median (IQR)	Presence of chest injuries, n (%)
Pedestrians	220 (41.9)	62 (51–74.5)	172 (78.2)
Motor vehicle drivers	98 (18.7)	43.5 (32–55)	81 (82.7)
Front-seat passengers	79 (15)	47 (26–62)	63 (79.7)
Back-seat passengers	29 (5.5)	53 (26–64)	20 (69)
Bicyclists	38 (7.2)	58.5 (49–67)	26 (68.4)
Motorcyclists	33 (7.4)	34 (24–40)	23 (69.7)
Tractor drivers	22 (4.2)	63.5 (54–71)	20 (90.9)

IQR – interquartile range.

Subjects who died at the scene in RTAs were more likely to have sustained chest injuries, which proved to be statistically significant (χ^2 = 14.99; df = 1; p = 0.000). Regional types of injuries analyzed by using the binary logistic regression are presented in Table 3.

From the total number of 525 subjects, 291 (55.4%) died at the scene of the accident or on their way to the hospital (average age 48.8 ± 19.3 years), while 234 (44.6%) out of 525 subjects outlived their injuries (average age 56.9 ± 18.7 years) for a certain period of time. Subjects who outlived their injuries were of older age (t-test = 4.89; p = 0.000). In 46 (8.8%) out of 525 subjects, the main cause of death was a complication of injury (pneumonia, sepsis, thromboembolism, or fat embolism). Subjects who outlived the injuries differed in terms of the kind of their RTA involvement: pedestrians and bicyclists outlived their injuries more frequently, while motor vehicle drivers were more likely to die at the scene (Table 4).

The most frequent type of chest injury was the fracture of the ribs on both sides of the chest. The odds for subjects who died at the scene in RTAs to have sustained fracture of the ribs on both sides of the chest is approximately two times higher than for the other subjects who outlived the accidents for some time. The presence of different rib cage fractures analyzed by using binary logistic regression is presented in Table 5.

The association of lung parenchymal injuries with rib fractures was statistically significant (χ^2 = 109.563; df = 6; p = 0.000). The most common type of lung injury was bilateral lung contusion (122 out of 525 subjects, i.e. 23.2%), and odds that the subjects who died at the scene to have sustained this type of injury were twice as high as for the rest of the subjects (OR 1.816; 95% CI 1.189–2.773). The odds of occurrence of bilateral lung lacerations in those who died instantly were approximately four times higher than in the other subjects (OR 4.098; 95% CI 2.017–8.324).

Subjects who died at the scene of the accident had frequently sustained injuries of the heart and the aorta (Table 6).

Table 3

Regional types of injuries analyzed by using the binary logistic regression

Types of injuries	Subjects who died at the scene, n (%)	Subjects who outlived the injuries, n (%)	Crude OR (95% CI)	p-value
Chest injury	245 (60)	163 (40)	1.778 (1.076–2.940)	< 0.05
Chest and head injury	134 (55.6)	107 (44.4)	0.397 (0.231–0.684)	< 0.05
Chest and abdomen injury	128 (68.1)	60 (31.9)	2.320 (1.523–3.533)	< 0.05
Chest, abdomen, and head injury	73 (70.9)	30 (29.1)	3.208 (1.467–7.016)	< 0.05

OR – odds ratio; CI – confidence interval.

Table 4

The distribution of subjects according to the type of road traffic accidents (RTAs) participation and outliving period

RTA participants	Subjects who died at the scene, n (%)	Subjects who outlived the injuries, n (%)	p-value (χ^2 test)
Pedestrians	101 (45.9)	119 (54.1)	< 0.05
Motor vehicle drivers	73 (74.5)	25 (25.2)	< 0.05
Front-seat passengers	49 (62.0)	30 (38.0)	> 0.05
Back-seat passengers	17 (58.6)	12 (41.4)	> 0.05
Bicyclists	12 (31.6)	26 (68.4)	< 0.05
Motorcyclists	24 (58.3)	15 (41.7)	> 0.05
Tractor drivers	15 (68.2)	7 (31.8)	> 0.05

Table 5

Presence of different rib cage fractures analyzed using binary logistic regression

Place of fracture	**Subjects who died at the scene, n (%)**	**Subjects who outlived the injuries, n (%)**	**Crude OR (95% CI)**	***p*-value**
Sternum	1 (0.3)	3 (1.3)	0.266 (0.027–2.569)	> 0.05
Ribs on one side	36 (12.4)	43 (18.4)	0.627 (0.388–1.014)	> 0.05
Ribs on both sides	198 (68)	114 (48.7)	2.241 (1.571–3.198)	< 0.05
Ribs on both sides with sternum	119 (40.9)	57 (24.4)	2.148 (1.471–3.139)	< 0.05
Thoracic spine	48 (16.5)	14 (6)	3.104 (1.665–5.786)	< 0.05

OR – odds ratio; CI – confidence interval.

Table 6

The distribution of subjects according to the presence of heart and aortic injuries and outliving period

Heart and aortic injuries	Subjects who died at the scene, n (%)	Subjects who outlived the injuries, n (%)	p-value (χ^2 test)
Heart tamponade	6 (2.1)	0	< 0.05
Heart contusions	13 (4.5)	6 (2.6)	> 0.05
Rupture of pericardium	14 (4.8)	3 (1.3)	< 0.05
Heart destruction	39 (13.4)	0	< 0.05
Hematoma of adventitia aortae	90 (30.9)	12 (5.1)	< 0.05
Aortic rupture	68 (23.4)	8 (3.4)	< 0.05

The odds of occurrence of pericardial rupture in those who died at the scene were approximately five times higher than in the other subjects (OR 4.730; 95% CI 1.341–16.685), while the odds of occurrence of aortic rupture in those who died at the scene were approximately nine times higher than in the other subjects (OR 9.388; 95% CI 4.404–20.015). Aortic adventitial hematoma was significant, as well, hence the odds of occurrence of this type of injury were approximately six times higher for the subjects who died at the scene of the accident (OR 6.075; 95% CI 2.058–17.929).

Haemothorax was identified in 206 (39.2%) out of 525 subjects, while in 203 (98.5%) out of 525 of them, combinations of haemothorax and rib fractures occurred, and haemopneumothorax was identified in 85 (41%) out of 525 subjects. The connection between haemothorax and fractured ribs was statistically significant (χ^2 = 94.605; df = 1; p = 0.000). Unilateral and bilateral pneumothorax were often accompanied by rib fractures, which was statistically significant (χ^2 = 15.237; df = 1; p = 0.000 and χ^2 = 8.921; df = 1; p = 0.003). The occurrence of unilateral pneumothorax, bilateral pneumothorax, and haemothorax in subjects dying at the scene of the accident was statistically significant (Table 7).

Numerous risk factors (the existence of different chest injuries or demographic features) proved to be in significant connection with immediate deathly outcomes of RTAs in two groups of subjects. After adjusting the results for gender and occurrence of other chest injuries, only a few of the above-mentioned risk factors remained statistically significant to be associated with immediate deathly outcomes. The multivariate logistic regression resulted in strong associations (Cox & Snell R square 0.336, Nagelkerke R square 0.450, Hosmer-Lemeshow, χ^2 = 6.876, df = 8, p = 0.550, overall model accuracy of 77.1%). Details are presented in Table 8.

Table 7

Presence of pneumothorax/hemothorax, rib fractures and the outliving period

Pneumothorax/Hemothorax		Rib fractures		Subjects who died at the scene, n (%)	Subjects who outlived the injuries, n (%)	*p*-value (χ^2 test)
		Yes	No			
One–sided pneumothorax	Yes	53 (10.1)	1 (0.2)	46 (85.2)	8 (14.8)	< 0.05
	No	344 (65.5)	127 (24.2)			
Both–sided pneumothorax	Yes	36 (6.8)	1 (0.2)	30 (81.1)	7 (18.9)	< 0.05
	No	361 (68.8)	127 (24.2)			
Hemothorax	Yes	203 (38.7)	3 (0.6)	160 (77.7)	46 (22.3)	< 0.05
	No	194 (36.9)	125 (23.8)			

Table 8

Risk factors and time of death analyzed using multivariate logistic regression

Risk factors (independent variables)	Adjusted OR (95% CI)	*p*-value
Gender	1.588 (0.932–2.707)	> 0.05
Older than 51 years	0.334 (0.164–0.680)	< 0.05
Pedestrians	0.666 (0.321–1.383)	> 0.05
Motor vehicle drivers	2.703 (1.380–5.295)	< 0.05
Front-seat passengers	1.370 (0.511–3.668)	> 0.05
Back-seat passengers	0.571 (0.225–1.453)	> 0.05
Bicyclists	1.004 (0.362–2.786)	> 0.05
Motorcyclists	0.206 (0.024–1.779)	> 0.05
Tractor drivers	2.580 (0.777–8.567)	> 0.05
Fracture of sternum	0.162 (0.008–3.404)	> 0.05
Fractures of ribs on one side	0.229 (0.036–1.442)	> 0.05
Fractures of ribs on both sides	0.262 (0.042–1.619)	> 0.05
Fractures of ribs on both sides with Fracture of the sternum	0.283 (0.045–1.764)	> 0.05
Fracture of thoracic spine	4.173 (1.921–9.066)	< 0.05
One–sided lung contusions	1.183 (0.549–2.550)	> 0.05
Bilateral lung contusions	1.274 (0.640–2.539)	> 0.05
One–sided lung lacerations	0.889 (0.259–3.047)	> 0.05
Bilateral lung lacerations	1.885 (0.639–5.561)	> 0.05
One–sided lung disruption	1.097 (0.013–0.752)	< 0.05
Heart contusion	2.185 (0.472–10.113)	> 0.05
Rupture of pericardium	0.663 (0.175–2.517)	> 0.05
Hematoma of *adventitia aortae*	2.400 (0.576–10.002)	> 0.05
Aortic rupture	3.606 (1.157–11.240)	< 0.05
One–sided pneumothorax	5.619 (1.959–16.117)	< 0.05
Both–sided pneumothorax	1.864 (0.596–5.831)	> 0.05
Hemothorax	1.647 (0.556–4.877)	> 0.05
Chest injury	6.234 (0.899–43.254)	> 0.05
Chest and head injury	0.550 (0.278–1.089)	> 0.05
Chest and abdomen injury	0.361 (0.162–0.807)	< 0.05
Chest, abdomen, and head injury	3.606 (1.341–9.673)	< 0.05

OR – odds ratio; CI – confidence interval.

Discussion

The aim of this study was to estimate the frequency and characteristics of RTA chest injuries in the region of Kragujevac in order to better understand their significance and define preventive measures for the most vulnerable population categories. Demographic data revealed that males contributed to the total account of subjects in much higher numbers compared to females, and this was also applicable to the total number of the deceased and RTA participants pertaining to different categories. Similar results have been reported in studies conducted in Germany [16], Hungary [17], India [18], and Turkey [19], where men accounted for 70–85% of casualties in RTAs.

According to the results obtained in this study, tractor drivers were among the oldest of subjects, and comparable results have been reported in other studies, as well. In Portugal, for instance, most of the tractor drivers involved in RTAs are between 60 and 70 years old [20], while in Sweden, more than half of the casualties are aged 55 and above [21]. The most vulnerable subjects in this research were pedestrians, which is in accordance with conclusions of similar studies conducted in the world, where pedestrians made up to 45% of the deceased RTA participants in underdeveloped countries, 29% in developing countries, while in the developed countries, pedestrians approximately made up to 18% of the casualties [16, 22]. A high number of deceased pedestrians in the present research could be explained by a large number of decrepit and old vehicles, poor road infrastructure as well as irresponsible behavior of pedestrians. Pedestrians have been identified as the most numerous and the most heterogeneous category of traffic participants, and they are the least protected subjects. A great majority of the deceased pedestrians in RTAs were older than 65. These findings could be explained by the fact that elderly pedestrians have difficulties noticing potential dangers and do not respond to them on time. They frequently have dementia, hearing, or sight impairments, which also makes it more difficult for them to participate in traffic [17, 23, 24], while recovery from trauma is more demanding than in the younger population [10, 16]. The largest number of motorcyclists and passengers in motor vehicles was in the 35–45 age category, which included the working population. This also correlates to the results of the rest of the studies [25–28].

Seasonal differences were noticed regarding RTA deathly outcomes, and these could be explained by greater activity during summer and autumn as compared to winter, which is partially in accordance with the results from other studies [17, 19]. The smallest number of fatal RTAs took place on Mondays, the first workday of the week, i.e. when subjects were not tired, while the majority of fatal RTAs took place in the middle of the week and at weekends, when the working population was more exhausted and when the younger population was usually more active, due to restaurant visiting and alcohol abuse [17, 19].

In the present study, injuries of individual parts of the chest were identified in two-thirds of the subjects, head injuries came in second by incidence, and abdomen injuries were the least frequent, which largely coincides with results from other studies [16, 25]. Traffic injuries exhibit certain characteristics according to the type of injury and extension, which is explained by the presence of an enormous action force generated as a result of mass and acceleration multiplication that is absorbed by the body during an accident. The injury occurs due to the absorption of the external force upon impact, acceleration, or deceleration, whereas the body tends to maintain its original position and speed [29, 30]. According to this study, the majority of the deceased subjects were pedestrians, while due to the poly-phase mechanism of injury, chest injuries were among the most common types of trauma. Primary injuries sustained by pedestrians were caused by the first impact of the vehicle (usually in the legs), secondary injuries were caused by contact with the vehicle, while tertiary ones were caused by subsequent contact with the terrain as a result of falling against the ground [29, 31]. Depending on the profile of the front end of the car, the pedestrian struck was either thrown forward in the direction of movement in cases of the bonnet front being high and blunt or scooped up onto the bonnet top, as with many slope-fronted modern vehicles. If the car speed is appreciable, the body can be thrown into the air or knocked down flat with a severe impact [11, 29–31]. Motor vehicle drivers sustained direct chest injuries due to the impact against the front part of the vehicle interior, i.e. the steering wheel, as well as hyperextension and deceleration injuries [32–34]. The large percentage of chest injuries among tractor drivers in this study sample could be explained by the characteristics of the vehicle and the mechanism by which the accident occurred. Namely, these are usually tractors without a cab from which drivers can be knocked out of rather easily. Furthermore, the tractors or implement machinery could turn over, or trailers could tip and end on top of the driver, and in those instances, chest injuries are inevitable.

Subjects who died at the scene of the accident are virtually twice as more likely to have sustained chest trauma than the other subjects, which is in correlation with El-Menyar et al. [3], who point out that such chances are approximately two times higher if chest injuries are sustained. The chances that subjects who have died at the scene sustained simultaneous chest and abdominal injuries are more than two times higher, while the chances for the occurrence of simultaneous injuries to the head, abdomen, and chest are more than three times higher for subjects who died at the scene. Similar results have been reported in other studies, according to which subjects with simultaneous chest, head, and abdominal injuries were most likely to die at the scene or during the first few hours [3, 35] following the accident.

In this study, more than half of the subjects died at the scene of the accident or on their way to a healthcare facility, while the remaining ones outlived their injuries for a certain period of time. This is in accordance with the data from other studies, in which approximately 50% of the subjects died at the scene or on their way to the hospital [17, 19]. In several studies, the published results deviate from those presented here, where the mortality rate at the scene of the accident is approximately 65% [16, 18], while Reddy et al. [25] stated that only 20% of subjects died at the scene. The organizational structure of the services for transporting injured persons, technical equipment of vehicles, and availability of vehicles could explain the differences in the aforementioned results. Subjects who died at the scene were younger compared to those who died in the hospital because these are mainly motor vehicle drivers and motorcyclists who are prone to risky behavior, and they suffer from serious injuries, which correlates to the results of other studies [17]. The results of this study accentuate that a large number of subjects who died at the scene of the accident pertained to the group of motor vehicle drivers and motorcyclists, who were classified in the group of younger RTA subjects. Bicyclists were the category of subjects who outlived their injuries most frequently. This could be explained by the distribution of injuries, localized mostly in the pelvic region and lower limbs, and least often in the chest area. It is important to mention that one-quarter of the bicyclists experienced pneumonia complications during hospitalization. A similar distribution of bicyclist injuries is evidenced by other certain studies [17, 36, 37].

Rib fractures are among the most frequent injuries in RTAs, with a share of 60–70% [5, 25]. The authors established that rib fracture was followed by damaged blood vessels and haemothorax, as this was largely present in all subjects. Subjects with bilateral fractures of the ribs and bilateral fractures of the ribs accompanied by sternal fracture were approximately twice as likely to die at the scene. In their study, Kent et al. [38] found that the odds ratio for death of younger subjects (aged 18–45) with rib fractures was smaller than for older subjects (over 64 years). Regardless of the presence or absence of concomitant trauma, subjects with rib fractures are at a significantly increased risk of in-hospital mortality [38].

Lung contusions were either caused by the effects of direct force originating from the fractured ribs, or via the effects of indirect force on lung tissue, in cases without rib fractures. Bilateral lung contusions were the most frequent type of injury of intrathoracic organs of the following RTA subjects: pedestrians, passengers, bicyclists, motorcyclists, and tractor drivers. Similar results have been reported in other studies [3, 25].

Subjects with myocardial rupture and tamponade died at the scene of the accident. In cases of myocardial rupture, death occurs within a few moments, and the diagnosis is most frequently made during autopsy [39]. According to the results of this study, the aortic rupture was the most frequent injury of intrathoracic organs in motor vehicle drivers and front-seat passengers. Aortic rupture is classified in the group of deceleration thoracic injuries, most commonly occurring in motor vehicle collisions, with front-seat occupants being the most vulnerable category [11, 13].

By analyzing the occurrence of different types of chest injuries in subjects, the authors obtained results that accentuated the relevance of certain types of injuries and the characteristics of deathly outcomes at the scene of the accident. Motor vehicle drivers were nearly three times more likely to die at the scene when compared to other subjects. This could be explained by the fact that motor vehicle drivers frequently sustain aortic rupture, pneumothorax, or haemothorax, which are life-threatening injuries that dramatically increase the chances for deathly outcomes at the scene of the accident. According to the obtained results, subjects who died at the scene of the accident are highly likely to have sustained aortic rupture, fracture of the thoracic spine, and pneumothorax.

Unlike other studies that employ data from all RTAs [3, 15, 22, 40], the authors only used the data on RTAs with fatal outcomes, i.e. autopsy reports. This could explain the partial difference between the results obtained herein and certain results reported by other global studies. The present results should be interpreted considering several limitations: the absence of traffic police reports from the scene of the accident, limited geographical area, exclusion of children under 14 years of age and of subjects shorter than 150 cm. These would provide data on the exact time of an RTA, road conditions at the time of the accident, traffic accident expertise (the type of vehicle, speed of impact), application of protective gear (seatbelts, helmets), as well as the extent of driving experience of RTA participants.

Conclusion

The majority of fatalities in RTAs were male pedestrians, with the average age being 51, who died after outliving their injuries for a certain period of time. Chest injuries were the most frequent in such accidents, and the most common type of injury was rib fracture combined with haemothorax. Chest injuries were often life-threatening or result in serious health consequences.

Performing autopsy in cases of fatal RTAs is extremely important because it is the only way to identify all of the injuries and explain the mechanisms of their occurrence; hence the data obtained in such procedures are irreplaceable.

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