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# Abdominal injuries in road traffic accidents – an autopsy study

## Povrede trbuha u saobraćajnim nezgodama – autopsijska studija

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**Abstract**

**Background/Aim.** Traffic accident injuries are a major public health problem worldwide, with millions of people dying every year. Although the improvement of traffic safety is based on preventive action, it is necessary to conduct an analysis of victims in traffic in order to prevent future traffic accidents with the help of such findings. The aim of the study was to determine the manner of occurrence of abdominal injuries (AIs), gender differences, and the sitting position in the vehicle that affects the severity of AIs, as well as which AIs lead more often to fatalities in traffic accidents. **Methods.** Materials for the present study were collected from the medico-legal autopsies, showing AIs that occurred in road traffic accidents. The total number of people who died from sustained injuries or complications of the injuries after road traffic accidents was 525. **Results.** In the study sample, 38.3% of subjects sustained abdominal trauma. Men were more likely to have AIs, and passengers in the front seat and motorcycle drivers were identified as the most vulnerable category of these types of injuries. The liver was the most commonly injured abdominal organ. Liver destructions, liver lacerations, spleen lacerations, intestinal injuries, the simultaneous occurrence of head, chest, and AIs, or the simultaneous occurrence of head and AIs in a higher percentage led to death at the scene. **Conclusion.** The results of this study represent the basis for creating educational content for all traffic participants as well as the legislation in the field of traffic safety.

**Key words:**
**abdominal injuries; accidents, traffic; autopsy; cause of death; risk assessment; sex factors.**

**Apstrakt**

**Uvod/Cilj.** Povrede u saobraćajnim nezgodama, u kojima milioni ljudi umiru svake godine, predstavljaju veliki problem javnog zdravlja širom sveta. Iako se unapređenje bezbednosti saobraćaja zasniva na preventivnom delovanju, neophodno je sprovesti analizu nastradalih u saobraćaju, kako bi se uz pomoć tih rezultata sprečile buduće saobraćajne nezgode. Cilj rada bio je da se utvrde način nastanka povreda trbuha (PT), razlike prema polu i položaj sedenja u vozilu koji utiče na težinu PT, kao i vrste PT koje češće dovode do smrtnog ishoda u saobraćajnim nezgodama. **Metode.** Materijal za studiju prikupljen je iz rezultata sudskomedicinskih obdukcija, kojima su ustanovljene PT nastale u saobraćajnim nezgodama. Ukupan broj osoba umrlih od zadobijenih povreda ili komplikacija povreda nakon saobraćajnih nezgoda bio je 525. **Rezultati.** U analiziranom uzoku, PT imalo je 38,3% preminulih osoba. Muškarci su češće imali PT, a putnici na prednjem sedištu i vozači motocikala su bili najranjivija kategorija za nastanak tih vrsta povreda. Jetra je bila najčešće povređeni organ trbuha. Destrukcija i laceracija jetre, laceracija slezine, povrede creva, istovremene povrede glave, grudnog koša i PT ili istovremene povrede glave i PT dovodili su u visokom procentu do momentalne smrti na mestu saobraćajne nezgode. **Zaključak.** Rezultati ove studije predstavljaju osnovu za kreiranje obrazovnih sadržaja za sve učesnike u saobraćaju, kao i kreiranje zakonske regulative u oblasti bezbednosti saobraćaja.

**Ključne reči:**
**abdomen, povrede; udesi, saobraćajni; autopsija; smrt, uzrok; rizik, procena; pol, faktori.**

### Introduction

Along with industrialization and scientific and technological development in the recent century, trauma and its complications have become an important issue, as it is one of the most prevalent causes of fatalities and morbidity worldwide [1, 2]. Trauma is the most frequent cause of death in the first four decades of life, and it remains a major public health

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problem in every country, regardless of the level of socioeconomic development (both in developing and developed countries) [3–5].

The abdomen is the third most common injured region, and abdominal injuries (AIs) are the cause of considerable morbidity and mortality. The abdominal area is often exposed to injury due to its anatomical position, size it occupies, and minimal bone protection. Around 3/4 of cases of abdominal trauma result from road traffic accidents (RTA), while only 1/4 of cases result from falling from height and other causes [6]. The incidence of AIs in RTA has decreased because of road and car safety improvements, but they continue to represent life-threatening situations. The high number of AIs with severe consequences, even death in RTA, can be explained by an increased number of powerful motor vehicles as well as increased travel speeds [7–9]. When two objects collide, each of them has an amount of energy that is in a linear relationship with mass and exponential with velocity. As objects collide, energy gets transferred from one object to another depending on the direction, speed, position, and nature of the objects. That is why the relationship between velocity and mortality from road traffic collisions is exponential. AIs are usually associated with injuries of other body regions, so these injuries may be overlooked in patients with severe head, chest, and limb injuries or injuries of the pelvis [10].

The aim of this study was to determine the frequency and characteristics of AIs due to RTA in order to better understand their significance and define preventive measures for the most vulnerable population categories.

## Methods

An epidemiological retrospective analytical autopsy study of AIs was conducted. Materials for the study were collected from the medico-legal autopsies, which presented AIs that occurred in RTA at the University Clinical Center of Kragujevac, Department of Forensic Medicine and Toxicology. The total number of studied deceased persons was 525 (of all 1,366 conducted autopsies performed on the territory of central Serbia, Kragujevac and the surrounding, in the period from 2001–2016). They died from sustained injuries or complications of the injuries after RTA. This study was conducted with the approval of the Ethics Committee of the University Clinical Center of Kragujevac (No. 01/13221).

Detailed information about the deceased was collected from different sources, including the request for a medico-legal autopsy obtained from competent courts or prosecutions, autopsy examination findings, and relevant clinical history found upon admission to the hospital and subsequently. Subjects were analyzed in terms of gender, age, and type of involvement in traffic accidents (pedestrians, motor vehicle drivers, front-seat passengers, rear-seat passengers, bicyclists, motorcyclists, and tractor drivers). AIs were classified into the following groups: liver injuries (lacerations, destructions, and subcapsular hematomas), spleen injuries (lacerations and destructions), intestinal injuries (intestinal contusions and intestinal rupture, mesentery hemorrhages and ruptures), kidney injuries (destructions, contusions, and lacerations), and urinary bladder injuries (hemorrhages of the bladder wall and ruptures). In addition, the analysis included the simultaneous occurrence of abdominal trauma and injuries of the chest or head. When considering the outliving period, the subjects were divided into two categories: subjects who died at the scene of the accident or on the way to the hospital and those who outlived their injuries for a certain period of time (6 hrs, 24 hrs, 72 hrs, 7 days, 14 days, 30 days).

### *Data analysis*

Statistical Package for Social Sciences – SPSS for Windows, Version 22 (SPSS Inc. Chicago, IL) was used for data processing. All numerical variables were tested with the Shapiro-Wilks and Kolmogorov-Smirnov tests for normal distribution. According to the data distribution, suitable descriptive statistics were employed (mean values with standard deviation). Student's *t*-test was used to estimate the differences between the variables that showed the parametric distribution. In variables that showed a nonparametric distribution, the Kruskal-Wallis test and Pearson's $\chi^2$ test (with Yates correction) were applied. Binary logistic regression was chosen for analyzing the connection of dichotomous dependent variables (death on the spot vs. death after the outliving period) and observational independent variables (injuries of certain body parts). 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 was considered significant.

## Results

### *Demographic analysis*

The study included subjects from 16 to 92 years old. The study excluded subjects younger than 14 years of age and those shorter than 150 cm. In the study sample, 201 (38.3%) subjects sustained abdominal trauma. Among all fatal RTA subjects with detected AIs, the males accounted for 3/4 of the subjects (152 males and 49 females). The average age of women was 52 ± 20.2 years and average age of men was 47.4 ± 18.9 years, but there was no statistically significant difference ($t$ = -1.463; $p < 0.001$). Although there were slightly more RTA subjects with abdominal trauma in the 15–35 age group, the statistically significant difference in the number of participants per group was not found ($\chi^2$ = 3.981; df = 3; $p$ = 0.264). The distribution of RTA subjects with AIs by age range and gender is represented in Table 1.

RTA subjects with AIs (average age 48.6 ± 19.2 years) were younger than other subjects without AIs (average age 54.8 ± 19.1 years), which was statistically significant ($t$ = 3.647; $p < 0.001$).

There was a statistically significant difference among the type of road users ($\chi^2$ = 194.423; df = 6; $p < 0.001$). The

**Table 1**

**The distribution of road traffic accidents subjects with abdominal injuries by age range and gender**

| Age range (years) | Men | Women | Total |
|---|---|---|---|
| 15–35 | 47 | 10 | 57 |
| 36–50 | 37 | 10 | 47 |
| 51–65 | 34 | 12 | 46 |
| > 65 | 34 | 17 | 51 |
| Total | 152 | 49 | 201 |

**All values are expressed as numbers.**

most vulnerable RTA subjects were front-seat passengers (39 out of 79, i.e., 49.4%). In terms of the frequency of AIs, motor vehicle drivers were in second place (44 out of 98, i.e., 45%). Among bicyclists, AI was present in the smallest number (5 out of 38, i.e., 13%) of RTA subjects.

*Most frequently injured organs*

Liver injuries were registered in 138 (26.3%) of 525 fatal RTA. The most common injuries were liver destruction (77, i.e., 14.7%) and liver lacerations presented in 58, i.e., 11%, fatal RTA. Subcapsular hematomas were found in only 3 subjects.

There was a statistically significant difference in the presence of liver injuries according to the type of participation in RTA ($\chi^2 = 21.824$; df = 6; $p = 0.003$). The most common liver injury was among front-seat passengers (30 out of the total 79), compared to other subjects in RTA, which was statistically significant ($\chi^2 = 5.867$; df = 1; $p = 0.015$). Among bicyclists, liver injury was present in the smallest number ($\chi^2 = 8.211$; df = 1; $p = 0.004$), which was statistically significant compared to other participants (Table 2).

One in five RTA subjects (106, i.e., 20.2%) had spleen injuries. The spleen was most often destructed (85, i.e., 16%), while lacerations were much less present (21, i.e., 4%). According to the type of participation in RTA, a significant difference in the prevalence of spleen injuries was observed ($\chi^2 = 18.388$; df = 6; $p = 0.010$), as presented in Table 2. The spleen injury was most common in front-seat passengers (25 out of the total 79 front-seat passengers, i.e., 31.6%), compared to other subjects in RTA, which is statistically significant ($\chi^2 = 6.759$; df = 1; $p = 0.009$).

Intestinal injuries were present in 93 (17.7%) RTA subjects. For easier analysis of intestinal injuries, we observed mesentery hemorrhages (58, i.e., 11%) and mesentery ruptures (31, i.e., 5.9%), while intestinal contusions and intestinal ruptures were present in significantly smaller numbers.

Kidney injuries were present in 34 (6.5%) RTA subjects. For easier analysis of kidney injury, we observed the following: destructions 20 (3.8%), contusions 9 (1.7%), and lacerations 5 (1%). Urinary bladder injuries were present in 29 (5.5%) RTA subjects. Hemorrhages of the bladder wall were present in 20 (3.8%), while bladder wall ruptures were present in only 9 (1.7%) cases. Depending on the type of fatal participants in RTA, injuries to the intestines, kidneys, and bladder did not show statistical significance (Table 2).

*Combined injuries*

According to our study, the liver was the most commonly injured abdominal organ, but liver injuries were often associated with injuries to other abdominal or extra-abdominal organs. The most commonly involved organ with liver was the spleen, 52% (72 of all 138 subjects with liver trauma), which is statistically significant ($\chi^2 = 116.166$; df = 1; $p < 0.001$). Associated injuries of the liver and intestines were in second place with 39% (54 of all 138), and it was also statistically significant ($\chi^2 = 57.930$; df = 1; $p < 0.001$). Associated injuries of the liver and kidney, 18% (25 of all 138), as well as liver and urinary bladder, 14% (19 of all 138), were less common but statistically significant, as presented in Table 3 with the results of the $\chi^2$ test.

**Table 2**

**Frequency of liver, spleen, intestines, kidney, and urinary bladder injuries according to the type of participation in road traffic accidents (RTA)**

| RTA subjects | Injuries | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | liver | | spleen | | intestines | kidney | urinary bladder | |
| | yes | no | yes | no | yes | yes | yes | |
| Pedestrians | 51 (23.2) | 169 (76.8) | 33 (15.0) | 187 (85.0) | 37 (16.8) | 12 (5.5) | 12 (5.5) | 220 (100) |
| Motor vehicle drivers | 32 (32.7) | 66 (67.3) | 27 (27.6) | 71 (72.4) | 23 (23.5) | 7 (7.1) | 6 (6.1) | 98 (100) |
| Front-seat passengers | 30 (38.0) | 49 (62.0) | 25 (31.6) | 54 (68.4) | 18 (22.8) | 8 (10.1) | 6 (7.6) | 79 (100) |
| Rear-seat passengers | 4 (13.8) | 25 (86.2) | 3 (10.3) | 26 (89.7) | 3 (10.3) | 3 (10.3) | 1 (3.4) | 29 (100) |
| Bicyclists | 2 (5.3) | 36 (94.7) | 4 (10.5) | 34 (89.5) | 2 (5.3) | 1 (2.6) | 1 (2.6) | 38 (100) |
| Motorcyclists | 12 (30.8) | 27 (69.2) | 10 (25.6) | 29 (74.4) | 7 (18) | 3 (7.7) | 2 (5.1) | 39 (100) |
| Tractor drivers | 7 (31.8) | 15 (68.2) | 4 (18.2) | 18 (61.8) | 3 (13.6) | – | 1 (4.5) | 22 (100) |
| Total | 138 (26.3) | 387 (73.7) | 106 (20.2) | 419 (79.8) | 93 (17.7) | 34 (6.5) | 29 (5.5) | 525 (100) |

**All values are expressed as numbers (percentages).**

**Table 3**

**Combined liver injuries and injuries of other abdominal organs in fatal road traffic accidents subjects**

| Abdominal organs | Injuries | Liver | | Total | $\chi^2$ | df | *p*-value |
|---|---|---|---|---|---|---|---|
| | | yes | no | | | | |
| Spleen | yes | 72 (13.7) | 34 (6.5) | 106 (20.2) | 116.166 | 1 | 0.000 |
| | no | 66 (12.6) | 353 (67.2) | 419 (79.8) | | | |
| Kidney | yes | 25 (4.8) | 9 (1.7) | 34 (6.5) | 39.310 | 1 | 0.000 |
| | no | 113 (21.5) | 378 (72.0) | 491 (93.5) | | | |
| Urinary bladder | yes | 19 (3.6) | 10 (1.9) | 29 (5.5) | 22.286 | 1 | 0.000 |
| | no | 119 (22.7) | 377 (71.8) | 496 (94.5) | | | |
| Intestines | yes | 54 (10.3) | 39 (7.4) | 93 (17.7) | 57.930 | 1 | 0.000 |
| | no | 84 (16.0) | 348 (66.3) | 432 (82.3) | | | |

**All values are expressed as numbers (percentages).**

It is important to note that about 1/3 of the subjects, 35.8% (188 out of 525), suffered from the concomitant chest and AIs, 21% (110 out of 525) sustained concomitant head and AIs, while the simultaneous occurrence of chest, head, and AIs was identified in 19.6% (103 out of 525) of instances ($\chi^2 = 193.830$; df = 1; $p < 0.001$).

*Outliving after abdominal injuries*

In the group of fatal RTA participants who died at the scene, almost half of the subjects had some AI (Table 4).

In the group of fatal RTA subjects who outlived injuries for a certain period of time, 27.8% had an AI. RTA subjects with some AIs die more often at the scene of the accident, which is statistically significant ($\chi^2 = 18.934$; df = 1; $p < 0.001$). Details on outliving the RTA of subjects with AIs are shown in Table 5.

We also analyzed the prevalence of AIs in different RTA participants, and we observed a high prevalence of AIs in front-seat passengers and motor vehicle drivers who died at the scene of accidents (Table 6).

The existence of different AIs or concomitant injuries proved to be significantly connected with immediate deathly outcomes of RTA in two groups of subjects. After adjusting the results for gender and the occurrence of other AIs, only a few risk factors remained statistically significant to be associated with immediate deathly outcomes: the simultaneous occurrence of head, chest, and AIs; the simultaneous occur-

**Table 4**

**Outliving abdominal injuries (AIs) after road traffic accidents**

| | | A | B | Total |
|---|---|---|---|---|
| AIs | yes | 136 (46.7) | 65 (27.8) | 201 (38.3) |
| | no | 172 (53.3) | 167 (72.2) | 324 (61.7) |
| Total | | 291 (100) | 234 (100) | 525 (100) |

**All values are expressed as numbers (percentages) of subjects who died at the scene (A) and outlived the AIs (B).**

**Table 5**

**Details on outliving the road traffic accidents of the subjects with abdominal injuries (AIs)**

| Time | 6 h | 24 h | 72 h | 7 d | 14 d | 30 d | Total |
|---|---|---|---|---|---|---|---|
| AIs | 29 (14.4) | 12 (6) | 2 (1) | 10 (5) | 6 (3) | 6 (3) | 65 (27.8) |

**All values are expressed as numbers (percentages) of subjects who outlived the AIs.**
**h – hours; d – days.**

**Table 6**

**Prevalence of abdominal injuries (AIs) in participants of different road traffic accidents (RTA) depending on outliving injuries**

| RTA subjects | Died at the scene | Outlived the AIs | Total |
|---|---|---|---|
| Pedestrians | 48 (61.5) | 30 (38.5) | 78 (100) |
| Motor vehicle drivers | 35 (79.5) | 9 (20.5) | 44 (100) |
| Front-seat passengers | 29 (74.4) | 10 (25.6) | 39 (100) |
| Rear-seat passengers | 5 (62.5) | 3 (37.5) | 8 (100) |
| Bicyclists | 2 (40) | 3 (60) | 5 (100) |
| Motorcyclists | 12 (70.6) | 5 (29.4) | 17 (100) |
| Tractor drivers | 5 (50) | 5 (50) | 10 (100) |
| Total | 136 (67.7) | 65 (32.3) | 201 (100) |

**All values are expressed as numbers (percentages).**

rence of head and AIs; liver destructions, liver lacerations, spleen laceration, and intestinal injuries. The odds of occurrence (OO) of simultaneous abdominal and chest injuries in those who died instantly were approximately two times higher than in other subjects (OR 2.277; 95% CI 1.567–3.309; $p < 0.001$), but the occurrence of simultaneous abdominal, chest, and head injuries were 3.6 times higher (OR 3.606; 95% CI 1.341–9.673; $p = 0.002$).

Liver destructions were present in 61 (79.2%) RTA subjects who died at the scene of the accident ($\chi^2 = 19.562$; df = 1; $p < 0.001$), and the OO of liver destructions in those who died at the scene are more than three times higher than in other subjects (OR 3.614; 95% CI 2.022–6.460; $p < 0.001$). Similar results were present in the case of liver lacerations. Liver lacerations were present in 45 (77.6%) RTA subjects who died at the scene of the accident ($\chi^2 = 11.969$; df = 1; $p = 0.002$), and the OO of liver lacerations in those who died at the scene are approximately three times higher than in other subjects (OR 3.110; 95% CI 1.634–5.917; $p = 0.002$).

Of the 21 RTA subjects with a spleen laceration, as many as 19, i.e., 90.5%, died at the scene of accidents, which showed statistical significance ($\chi^2 = 9.449$; df = 1; $p = 0.002$). The OO of spleen laceration in those who died at the scene are approximately eight times higher than in other subjects (OR 8.103; 95% CI 1.868–35.154; $p = 0.005$).

Death at the scene of the accident rather than outliving the injuries occurs more often in the RTA subjects with intestinal injuries ($\chi^2 = 6.344$; df = 1; $p = 0.012$), and the OO of intestinal injuries in those who died at the scene are approximately two times higher than in other subjects (OR 1.879; 95% CI 1.170–3.018; $p = 0.009$).

## Discussion

According to the Law of the Republic of Serbia, performing a medico-legal autopsy is obligatory after RTA if there is a suspicion of a criminal offense. In addition to defining the exact cause of death and injury mechanism, one of the objectives of the autopsy is a detailed description of all external and internal injuries on the body; therefore, the autopsy report is an important document in further court proceedings and can serve scientific purposes because it contains a lot of medical facts. This study was conducted to research the pattern and type of AIs and to identify the risk of injuries to organs in the abdomen after RTA. Furthermore, the aim of this study was to estimate the frequency and characteristics of RTA AIs according to the age and gender of subjects, type of participants in traffic, and time distribution of death after injury (time from injury to death).

Of all fatal road accident participants, AIs were present in 38.3% of cases, which is slightly more than in other published studies. The main reason for that is the fact that our study was conducted on fatally injured RTA participants (autopsy study), where detailed autopsy methods note any minimal injury [11–13]. According to the results of many studies [14–18], men are more commonly injured, and the ratio of men to women was about 3:1, and our results agree with that. The fact that males are usually the breadwinners of the families makes them more mobile and thus more prone to traffic accidents. The most common age range of the RTA subjects was 15–35 years, which correlates with the study conducted by Subedi et al. [17], and it can be explained by the fact that the participants of this age group are in the most active period of life, prone to proving and risky driving behavior [6].

Observing the type of participation in RTA, every second front-seat passenger had an AI, which characterizes them as the most vulnerable RTA subjects when it comes to AIs (49.4%). Motor vehicle drivers were in second place among the injured RTA subjects with AIs (45%). In a study conducted on participants inside the vehicle, Daskal et al. [19] concluded that passengers inside the vehicle (front-seat or rear-seat passengers) were found to be at higher risk of serious AI than motor vehicle drivers, which correlates with the results of our study. Töro et al. [18] and Goniewicz et al. [20] point out that injuries of the abdominal organs are more common among protected participants in traffic accidents (participants inside the vehicle – motor vehicle drivers and front-seat passengers) compared to unprotected participants (pedestrians, bicyclists, and motorcyclists) with a frequency of about 20%. The higher incidence of AIs in vehicle participants can be explained by the mandatory use of a seat belt. In all types of motor vehicle crashes, seat belts are effective for preventing head injuries and death but increase AIs. Seat belts are the most common source of AI because when the restrained occupant is subjected to high-speed deceleration, abdominal compression occurs [21–23]. In contrast, Subedi et al. [17] point out that pedestrians and motorcyclists are RTA participants with a higher frequency of AIs and explain that the reason is a high-speed impact and lack of body restraints. According to our results, the smallest number of AIs was in bicyclists (13%), which also correlates with the results of the mentioned studies [14–18, 20].

Every fourth RTA subject sustained a liver injury, so according to our results, it was the most commonly injured organ in the abdominal cavity. The high prevalence of liver injuries is explained by its size, fixation in the abdominal cavity, and the inelasticity of the tissue itself [11, 24]. Compression of the liver by the steering wheel causes the destruction of this organ. Several epidemiological studies have also reported the liver as the most commonly injured solid organ [11, 13, 17, 25]. There are studies in which the liver ranks second in frequency, just after the spleen [12, 26]. According to our results, the most common liver injury was destruction, which deviates from the literature data, according to which the most common liver injuries are lacerations [11, 13, 27]. In our study, the higher frequency of liver destruction can be explained by the high intensity of the force acting on the relatively weak and unprotected anterior abdominal wall during the RTA, resulting in severe injuries.

According to our results, the spleen is the most commonly injured organ after the liver, and it was found in every fifth RTA subject. Being struck by the intruded side door is the most common source of trauma in motor vehicle side collisions. Likewise, seat belt loading is a risk factor in some cases. Restrained drivers of small vehicles are subjected to

greater contact with the intruding vehicle. The side doors of heavier vehicles provide greater protection. However, unrestrained occupants sustained spleen injuries from instrument panel contact and the steering wheel. In autopsy studies after fatal traffic accidents, Tambuzzi et al. [28] and Reddy and al. [13] state that the spleen is second in frequency of injury after the liver, with a representation of about 18%, which is in correlation with the results of our study. Similar results have also been reported in other studies [11, 25, 27, 29], but some studies in the literature describe the spleen as the most commonly injured organ in the abdominal cavity with a much higher frequency [12, 26, 30, 31]. As with the liver, the most common spleen injury was destruction, which also deviates from the literature data, according to which the most common spleen injuries are lacerations [11, 13, 32].

With a similar frequency as spleen injuries of about 17%, intestinal injuries were present, primarily injuries in the form of mesentery hemorrhages. Intestinal injuries occur when a force acts on the anterior abdominal wall and presses them on the spinal column or due to the transmission of hydrostatic pressure through the fluid content in the intestines. There are studies in the literature in which intestinal injury was represented by 16% [33] and 17% [29], similar to our results. Intestines, especially the small intestine, are the most damaged abdominal viscera in blunt abdominal trauma (19%), which reflects large energy transfers in traffic accidents in fatal cases [34]. Watts and Fakhry [34] have indicated that RTA subjects are 1.5 times more likely to present abdominal hollow viscera lesions than other blunt trauma mechanisms. Faduyile et al. [11] reported a slightly smaller incidence of intestinal injury, about 11%.

Injuries to the kidneys (7%) and urinary bladder (6%) were observed in a significantly smaller number of fatalities in traffic accidents. Kidney injuries are the rarest due to their anatomical position – they are protected in the space between the spine and ribs and are isolated by a layer of fatty tissue. The same is for the bladder, which is protected by the pelvic bones. Kidney injuries are significant because they are often accompanied by massive retroperitoneal bleeding that can be fatal. These findings are partially consistent with previous results [13, 29, 35]. In their study, Shetty et al. [35] pointed out that the kidney was the most commonly injured solid abdominal organ, with a frequency of about 23%.

According to our results, liver trauma usually occurs associated with other AIs. The most commonly involved organs were the spleen (52%), intestines (39%), kidney (18%), and urinary bladder (14%). Scollay et al. [36] established that almost 90% of liver trauma patients sustained associated chest, head, and orthopedic injuries, or other AIs, among which the most commonly involved were spleen (24%), kidney (21%), intestines (17%), and urinary bladder (4%). Liver injury was also associated with multiple regional injuries, as Subedi et al. [17] and Talving et al. [37] highlighted in their research. The most common associated extra- AIs included chest injury (36%), head injury (21%), and combined head and chest injury (20%). Associated injuries significantly raised mortality. The literature also emphasizes the importance of associated injuries to the abdomen and other parts of the body, especially the chest [11, 12, 27, 38].

According to the results of our study, almost half of the RTA subjects who died at the scene and 1/3 of those who outlived injuries for a certain period of time had some AI. Almost 80% of motor vehicle drivers and 74% of front-seat passengers with some AIs died at the scene of accidents, which is explained by the frequent occurrence of concomitant injuries, which in total represent severe bodily injuries incompatible with life. Ndiaye et al. [39] point out that more than three-quarters of motor vehicle drivers died immediately, which concurs with our results. One of the most important characteristics of injuries in traffic accidents is a massive action of a force which is the product of mass and acceleration absorbed by the body during a traffic accident. The injury occurs due to the absorption of the external force upon acceleration, deceleration, or impact, whereas the body tends to maintain its primary position and speed. As AIs increase in severity, other organ systems may become involved, so total mortality may result from the cumulation of all damaged organs (only abdominal or combinations of abdominal and other). The chances that participants who have died on the spot sustained simultaneous chest and AIs are more than two times higher, while the chances for the occurrence of simultaneous injuries to the head, chest, and abdomen are more than three times higher for RTA participants who died on the spot. Other authors have come to similar conclusions, according to which subjects with simultaneous head, chest, and AIs were most likely to die at the scene of the accident or during the first few hours following the accident [38, 40–42]. According to the obtained results, RTA participants who died on the spot more frequently have spleen lacerations (8 times higher), liver injuries (destructions 3.6 times or lacerations 2 times higher), and injuries of the intestines (2 times higher).

## Conclusion

Road traffic participants are not a uniform population; they are exposed to different kinds of hazards depending on conditions prevailing in that region, hence presenting different epidemiological findings. This study may help to take safety measures, implement strict traffic rules, and educate people. The results of our study reveal a clear difference between different road participants, the incidence of AIs, as well as the outcome after injury.

The most common AIs were present among men in the 15–35 age group. Among the type of road users, the most vulnerable RTA subjects were front-seat passengers and motor vehicle drivers.

The liver is the most commonly injured abdominal organ, and liver injuries are often associated with injuries to other abdominal or extra-abdominal organs. About 1/3 of the subjects suffered from the concomitant chest and AIs. RTA subjects with some AIs more often die at the scene of the accident. Liver destructions, liver lacerations, spleen lacerations, intestinal injuries, the simultaneous occurrence of

head, chest, and AIs, or the simultaneous occurrence of head and AIs in a higher percentage lead to death at the scene.

This information can provide decisive data for the correct choice between the various diagnostic and therapeutic options for early diagnosis of potentially fatal occult injuries. This type of research is pioneering research in the territory where it was conducted. The results of this study represent the basis for the creation of educational content for all traffic participants, as well as the creation of legislation in the field of traffic safety. It is necessary to conduct such and similar research permanently in order to monitor the current state of suffering of traffic participants. Apart from the fact that such results serve to improve traffic safety, they also serve as a warning and encouragement that in the field of traffic safety, work must be done every day, as long as there are injured and killed traffic participants.

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