trauma care

Article

An Autopsy-Based Analysis of Fatal Road Traffic Collisions: How the Pattern of Injury Differs with the Type of Vehicle

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Abstract: In Italy, in only 2018, 3310 people died in road traffic accidents, more than in any other European country. Since the revelation of this occurrence, the authors carried out an analysis aimed at investigating if there was a difference in the injury patterns among different road users. A retrospective post-mortem study on road traffic fatalities was performed, which had been autopsied at the Institute of Forensic Medicine of Milan. First, the authors analyzed the epidemiological data of all the 1022 road traffic accidents subjected to an autopsy from 2007 to 2019. Secondly, further analysis of individual autopsy reports was carried out. For this purpose, 180 autopsies belonging to 5 different categories were analyzed: car, pedestrian, motorbike, bicycle, and truck. Seventy-six percent of road traffic fatalities were male, 54% were between 10 and 49 years of age, and 62% of the patients died before arriving at a hospital. “Multiple injuries” was the main cause of death. Traumatic brain injuries were particularly high in pedestrians and cyclists. In car, motorbike, and truck fatalities, thoracic and abdominal injuries were the most frequent. Therefore, pedestrians and cyclists had a higher prevalence for traumatic head injuries, while car, motorcycle, and truck occupants, on the other hand, had a higher prevalence for thoracic and abdominal injuries.

Keywords: road traffic collision; trauma; multiple injuries; pedestrians; cyclists; motorcyclists; car accidents; truck crashes

Citation: Tambuzzi, S.; Rittberg, W.; Cattaneo, C.; Collini, F. An Autopsy-Based Analysis of Fatal Road Traffic Collisions: How the Pattern of Injury Differs with the Type of Vehicle. *Trauma Care* **2021**, *1*, 162–172. https://doi.org/10.3390/traumacare1030014

Received: 3 August 2021
Accepted: 8 October 2021
Published: 13 October 2021

1. Introduction

Currently, road traffic accidents are still a major cause of death even in developed countries. Approximately 1.35 million people die due to road traffic collisions (RTC) each year, and 20–50 million sustain non-fatal injuries [1]. In 2018, there were around 23,400 people killed in Europe in RTCs [2]. In Italy alone, 3310 people died due to RTCs, which is the highest number of road traffic fatalities among all European countries [3]. RTCs are the leading cause of death for children and adults between the ages of 5 and 25. RTCs produce social and economic costs of 3% of a country’s gross domestic product [1]. Looking at the distribution among vehicles, it is possible to state that in 2016, nearly all the victims of fatal RTCs were either drivers or passengers in a car, motorbike, bicycle, or truck or pedestrians. Cars (46%), pedestrians (21%), and motorbikes (17%) make up 84% of all fatal RTCs [4]. The top three risk factors for road traffic accidents are distraction while driving (16.3%), right of way being ignored (14.2%), and high speeds (10.2%) [2]. Speeding increases the likelihood of an incident and its severity. Pedestrians have a 4.5-fold increased risk to die if they are hit by a vehicle traveling at 65 km per hour versus one traveling at 50 km per hour. Other risk factors are alcohol, drugs, the non-use of helmets, seatbelts, and child restraints, distractions like the use of mobile phones, unsafe vehicles and roads, inadequate emergency medical treatment, and enforcement of traffic laws [1].

To date, there are some studies on the injury pattern of one group of road users in fatal RTCs, but very few studies compare different groups of road users. It seems that head injuries are more common in pedestrians and cyclists than in motor vehicle occupants [5].

However, fatal injuries may be under-reported since, unfortunately, in many European countries, autopsies are rarely performed for all traffic accidents [6]. The city of Milan represents a small exception in this background; it is, in fact, one of the few in which an autopsy is always performed for any traffic-related death. In this context, the present study shows a glimpse at one of the largest Italian cities with the aim of understanding what effect the type of vehicle has on the pattern of injuries in a fatal road traffic collision and if there are differences between the individual road users.

2. Materials and Methods

A retrospective post-mortem study was carried out. It was divided into two parts: the former was the analysis of a database including 1022 fatal RTCs with general epidemiological information which focused on epidemiological variables, and the latter was the analysis of 180 autopsy reports of RTC victims, focusing on the causes of death and on the sustained injuries. The database of the Institute of Legal Medicine includes 1022 cases of fatal road traffic accidents in Milan and the hinterland from 2007 to 2019 which had autopsies. It was evaluated by the following categories: age, gender, position in the vehicle, and location of death certification. In order to learn more about the exact injuries sustained, further analysis of individual autopsy reports was required. For this purpose, the authors analyzed 180 autopsy reports belonging to 5 different categories: car, pedestrian, motorbike, bicycle, and truck. Concerning truck occupants, only 20 cases were analyzed, as these types of accidents are very rare. Instead, 40 autopsy reports for each of the other categories were assessed. The exclusion criteria were medical emergencies such as myocardial infarction that led to the incident in the first place. Aside from that, cases in which the person died more than 72 h (3 days) after the time of the incident were also excluded. Additionally, cases in which the victims did not die directly from the trauma of the incident but because of asphyxia were excluded. The autopsy report includes detailed information about injuries divided by each anatomical district. Information about the person, the incident, the injuries, and the cause of death were collected. The sustained injuries were divided into external, skeletal, and visceral injuries. These were further subdivided by anatomical region and organ.

3. Results

3.1. Epidemiological Data

Through analysis of the 1022 fatal road traffic collisions in Milan from 2007 to 2019, it emerged that 776 involved males (76%) and 240 involved females (24%). Most of the females who died in RTCs were pedestrians (139, 58%), followed by drivers (60, 25%) and passengers (41, 17%). Of the male sample on the other hand, 520 (67%) were drivers, 202 (26%) were pedestrians, and 54 (7%) were passengers. The highest ratio of deaths in RTCs occurred in road users which were in their twenties (184, 18%), thirties (163, 16%), forties (154, 15%), and then fifties (115, 11%). It continuously declined from the twenties up to the sixties (9%). The seventies (122, 12%) and eighties (109, 12%) saw another rise. Only 53 (6%) of the victims were younger than twenty years. On the whole, 391 (38%) deaths occurred during hospitalization, 385 (38%) were witnessed deaths, and 170 (17%) were unwitnessed deaths, while 76 (7%) of the deaths occurred during transfer to the hospital by emergency medical services. Therefore, 632 (62%) of the patients died before arrival at the hospital.

3.2. Autopsy Reports

From the analysis of the autopsy reports, it emerged that 136 (76%) of all road users died from multiple injuries, 42 (23%) died from a traumatic head injury, and 2 (1%) died from aortic rupture. The highest proportion of multiple injuries was found with 18 (90%) in truck occupants, followed by motorcyclists with 32 (80%), car occupants with 31 (78%), cyclists with 29 (72%), and pedestrians with 26 (65%).

Table 1 shows the sustained injuries per anatomical region for the different road users who died in RTCs.

Table 1. Injured anatomical region, including both skeletal and visceral injuries, per road user.

	Car	Pedestrian	Motorbike	Bicycle	Truck
Head (*n*; %)	32 (80)	38 (95)	28 (70)	37 (93)	16 (80)
Neck (*n*; %)	10 (25)	6 (15)	19 (48)	15 (38)	6 (30)
Thorax (*n*; %)	39 (98)	36 (90)	38 (95)	37 (93)	19 (95)
Abdomen (*n*; %)	29 (73)	22 (55)	28 (70)	24 (60)	15 (75)
Pelvis (*n*; %)	18 (45)	15 (38)	8 (20)	13 (33)	10 (50)
Limbs (*n*; %)	24 (60)	20 (50)	19 (48)	15 (38)	11 (55)

Head

The highest proportion of traumatic head injuries was sustained by pedestrians, followed by cyclists, car and truck occupants, and motorcyclists. Subdural and subarachnoid hematoma were more frequent in pedestrians and cyclists, followed by motorcyclists and car occupants. Motorcyclists were three times more likely to have a base than a top fracture of the neurocranium, and cyclists were nearly twice as likely to have this. Finally, both the exposition and destruction of cerebral parenchyma were more frequent in pedestrians than all the other types of road users.

Neck

Neck injuries were highest in motorcyclists, followed by cyclists, truck and car occupants, and pedestrians. The vast majority of motorcyclists sustained spinal cord injuries or transections, and trachea lesions were twice as frequent in motorcyclists compared with cyclists. Spinal cord injuries were also quite common in car occupants and pedestrians.

Thorax

Thoracic injuries were very high for all road users. Pedestrians were slightly less involved. The lungs and heart were more frequently injured in car occupants, followed by motorcyclists and cyclists. In particular, cardiac rupture was twice as frequent in car occupants compared with pedestrians. The most common blood vessel laceration was by far the one of the thoracic aorta. In 28 cases (around 60%), it ruptured at the isthmus, and this was most frequent in car occupants. Truck occupants had a similar injury pattern to the car occupants but with no cardiac ruptures.

Abdomen

Abdominal injuries were highest in truckers, followed by car occupants and motorcyclists. They were less common in cyclists and pedestrians. Compared with the other road users, car occupants experienced the highest number of liver and splenic lacerations, followed by motorcyclists. Cyclists had a similar injury pattern to pedestrians with slightly more liver and splenic lacerations. Renal injuries were less common, as well as intestinal injuries.

Pelvis

Pelvic injuries were highest in truck occupants and the least common in motorcyclists. On the whole, pelvic fractures were more common than bladder lacerations.

Limbs

Limb injuries were most often sustained by car occupants and least often sustained by cyclists.

All the details regarding life-threatening skeletal and visceral injuries are reported in Table 2. Moreover, for spinal cord injuries and aortic lacerations, we went deeper, assessing the exact locations of the injuries, and the findings obtained are shown in Figures 1 and 2.

Table 2. Life-threatening skeletal and visceral injuries by anatomical region and per road user.

	Anatomical Region	Car	Pedestrian	Motorbike	Bicycle	Truck
Head	Neurocranium Top (*n*; %)	19 (47.5)	22 (55)	6 (15)	15 (37.5)	9 (45)
	Neurocranium Base (*n*; %)	20 (50)	26 (65)	18 (45)	28 (70)	9 (45)
	Exposition of Cerebral Parenchyma (*n*; %)	5 (12.5)	9 (22.5)	3 (7.5)	4 (10)	2 (10)
	Destruction of Cerebral Parenchyma (*n*; %)	8 (20)	12 (30)	6 (15)	10 (25)	2 (10)
	Epidural Hematoma (*n*; %)	7 (17.5)	7 (17.5)	3 (7.5)	8 (20)	3 (15)
	Dura Mater Laceration (*n*; %)	7 (17.5)	6 (15)	3 (7.5)	9 (22.5)	5 (25)
	Subdural Hematoma (*n*; %)	16 (40)	24 (60)	18 (45)	24 (60)	8 (40)
	Subarachnoid Hematoma (*n*; %)	25 (62.5)	32 (80)	25 (62.5)	30 (75)	12 (60)
	Intraventricular Hemorrhage (*n*; %)	20 (50)	24 (60)	20 (50)	26 (65)	11 (55)
Neck	Esophagus Transection (*n*; %)	0 (0)	0 (0)	2 (5)	0 (0)	0 (0)
	Trachea Transection (*n*; %)	0 (0)	0 (0)	4 (10)	2 (5)	0 (0)
	Spinal Cord Injury and Transections (*n*; %)	12 (30)	11 (28)	16 (40)	8 (20)	5 (25)
Thorax	Left Lung Laceration (*n*; %)	8 (20)	7 (17.5)	9 (22.5)	8 (20)	3 (15)
	Right Lung Laceration (*n*; %)	10 (25)	7 (17.5)	9 (22.5)	9 (22.5)	4 (20)
	Pericardial Rupture (*n*; %)	12 (30)	12 (30)	9 (22.5)	15 (37.5)	4 (20)
	Cardiac Rupture (*n*; %)	10 (25)	5 (12.5)	3 (7.5)	6 (15)	0 (0)
	Superior Vena Cava Laceration (*n*; %)	0 (0)	1 (2.5)	2 (5)	2 (5)	0 (0)
	Pulmonary Vessels Laceration (*n*; %)	1 (2.5)	2 (5)	1 (2.5)	1 (2.5)	0 (0)
	Thoracic Aorta Laceration (*n*; %)	16 (40)	8 (20)	14 (35)	6 (15)	5 (25)
	Inferior Vena Cava Laceration (*n*; %)	1 (2.5)	2 (5)	2 (5)	1 (2.5)	1 (5)
	Diaphragm Laceration (*n*; %)	5 (12.5)	1 (2.5)	2 (5)	7 (17.5)	5 (25)
Abdomen	Abdominal Aorta Laceration (*n*; %)	0 (0)	1 (2.5)	0 (0)	1 (2.5)	1 (5)
	Liver Laceration (*n*; %)	26 (65)	12 (30)	22 (55)	15 (37.5)	10 (50)
	Splenic Laceration (*n*; %)	14 (35)	7 (17.5)	13 (32.5)	8 (20)	6 (30)
	Left Renal Artery Laceration (*n*; %)	3 (7.5)	2 (5)	4 (10)	4 (10)	1 (5)
	Left Kidney Laceration (*n*; %)	3 (7.5)	1 (2.5)	2 (5)	3 (7.5)	2 (10)
	Right Renal Artery Laceration (*n*; %)	1 (2.5)	4 (10)	3 (7.5)	3 (7.5)	0 (0)
	Right Kidney Laceration (*n*; %)	0 (0)	3 (7.5)	3 (7.5)	3 (7.5)	3 (15)
	Intestine Laceration (*n*; %)	0 (0)	1 (2.5)	2 (5)	1 (2.5)	3 (15)
Pelvis	Bladder Laceration (*n*; %)	1 (2.5)	2 (5)	1 (2.5)	2 (5)	0 (0)
	Pelvic fracture (*n*; %)	17 (42.5)	15 (37.5)	7 (17.5)	13 (32.5)	10 (50)
Limbs	Upper Limbs Fractures (*n*; %)	16 (40)	11 (28)	15 (38)	7 (18)	8 (40)
	Lower Limbs Fractures (*n*; %)	17 (43)	17 (43)	13 (33)	12 (30)	9 (45)

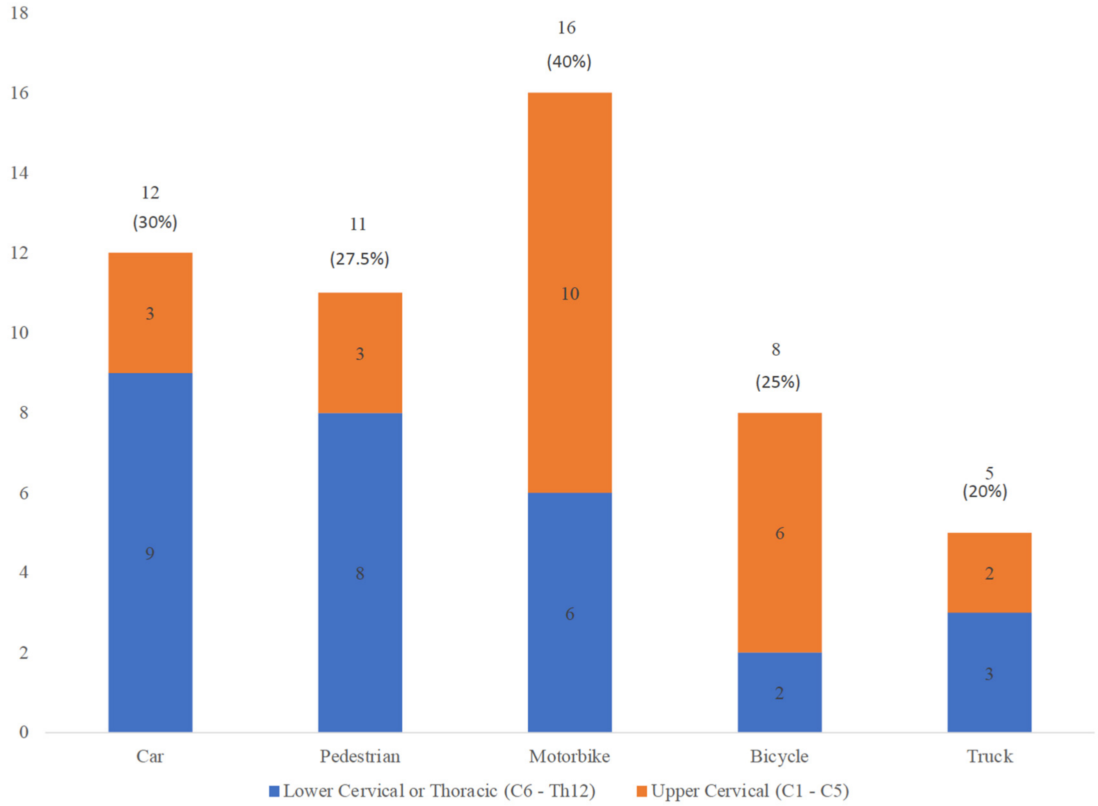

Figure 1. Locations of spinal cord injuries per road user.

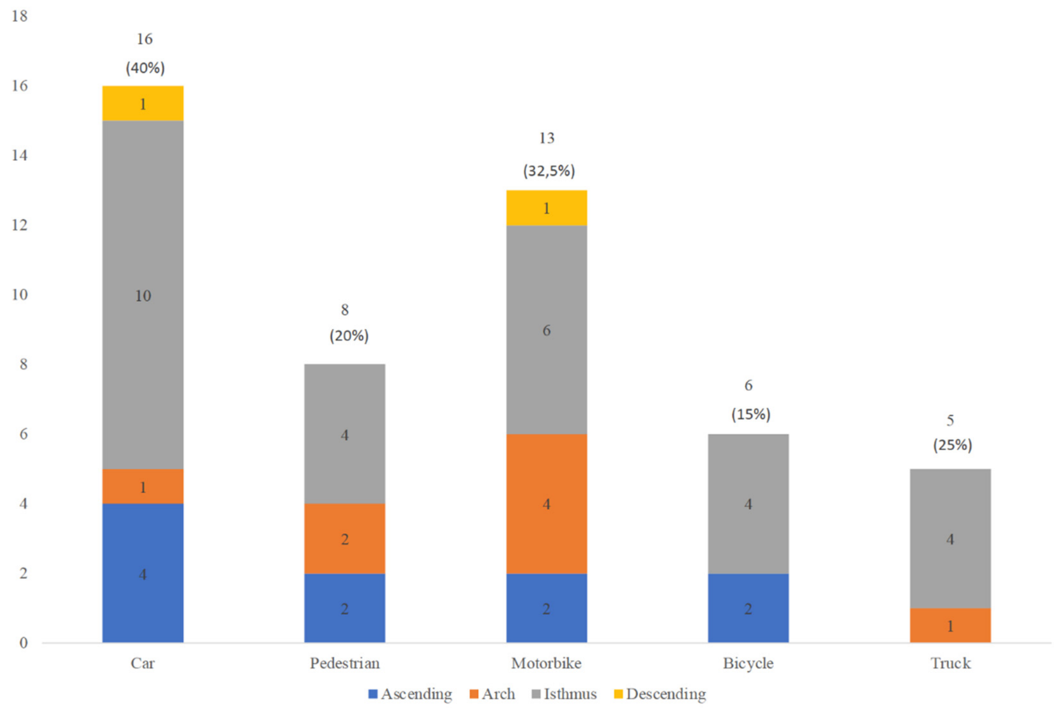

Figure 2. Locations of aorta injuries per road user.

4. Discussion

Based on the results from the database of the Institute of Forensic Medicine of Milan including 1022 road traffic fatalities from 2007 to 2019, males were three times more likely to die in a road traffic collision than women (76% vs. 24%). Fifty-eight percent of female road traffic fatalities were pedestrians, 25% were drivers, and 18% were passengers. Male fatalities were drivers in 67% of the cases, 26% were pedestrians, and only 7% were passengers. British studies found the following reasons: in Great Britain, men drive twice as many kilometers per year as women, and they also admit to driving under the influence of alcohol and drugs three times more often than women and score higher on having a risky, angry, and high-velocity driving style [5–8]. A German study in 2015 even showed that it is possible to determine the gender with a high accuracy based on the driving behavior during a 23-km virtual drive. Acceleration and speed were the most important variables to predict the gender of the test person [9]. Deaths due to RTCs in Milan are clearly a disease of the young, with around 54% of deaths occurring in people between 10 and 49 years of age. Both the male predominance and the young age are also confirmed by the WHO on a global level, as previously mentioned [1]. More than half of all patients (53%) died on the scene, and another 7% died on the way to a hospital. Therefore, 62% died before arrival at a hospital. This is in line with the results from other studies, with percentages ranging from 64 to 65% [10,11].

The analysis of the 180 autopsy reports of road traffic fatalities, with deaths between 2003 and 2019 and autopsied at the Institute of Forensic Medicine of Milan, found that multiple injuries (76%) and traumatic head injuries (23%) were the main cause of death in RTCs. This is not in line with other studies, which showed that traumatic head injuries were the cause of death in 51–53% of road traffic collisions [10–12]. This study also showed that five out of the six most common life-threatening injuries among all road users were cranial and encephalic injuries. The issue with the cause of death seems to be more of a definition problem, as most of the fatalities who died by multiple injuries had sustained severe head injuries. Many of the road traffic fatalities which fell into the category of "multiple injuries" as the cause of death might have died due to a combination of traumatic brain injuries and multiple injuries, or the traumatic head injury might have been the actual cause of death. For example, an autopsy-based study on 277 patients who died in road traffic accidents in Munich, Germany found that 39% of road users suffered a severe brain injury, 27% suffered severe thoracic injuries, and 12% presented both severe brain and thoracic injuries [13]. Thus, especially in road traffic fatalities, because of the multiple injuries that most people sustain, it seems to be difficult to state the exact cause of death.

The percentage of traumatic head injuries was particularly high in the groups of pedestrians and cyclists. A possible explanation could be the mechanism of injury, because pedestrians and cyclists often hit the windshield of a car before sustaining head injuries again by falling onto the street. The other users might also be more protected by airbags, seatbelts, and protective gear like proper helmets.

In car and truck occupants and motorcyclists, on the other hand, more thoracic and abdominal injuries were found.

4.1. Car Drivers

Sixty-five percent of car occupants sustained a cranial fracture, 78% sustained a traumatic brain injury, and 25% sustained a cervical injury. In particular, the non-use of seatbelts and expulsion through the windshield from the car cause severe head injuries [14]. Spinal cord injuries including transections were found in 30% of dead car occupants, and 7.5% involved the C1–C5 vertebrae of the upper spinal cord. Thoracic (98%) and abdominal injuries (73%) were highest among all road users. Twenty percent of the sample showed left lung lacerations, 25% showed right lung lacerations, 30% showed pericardial ruptures, 25% showed ruptures of the heart, 40% showed thoracic aorta lacerations, 12.5% showed lacerations of the diaphragm, 65% showed liver lacerations, and 35% showed splenic lacerations. No other road user sustained as many cardiac ruptures (25%) as car occupants. One of the reasons for that might be a high-velocity incident, the non-use of a seatbelt, and the consequent ramming into the steering wheel [14,15]. Moreover, 42.5% had fractured pelvises, as well as fractures of the extremities (in 40% of the cases a fracture of the upper extremities, and in 43% of cases the lower ones). Only truck occupants had similar fractures. Thoracic and abdominal viscera lacerations such as thoracic aorta lacerations, ruptures of the heart, and liver and splenic lacerations seem to have caused rapid exsanguination in many cases. In addition, skeletal injuries such as fractures of the pelvis, humerus, or femur seem to have caused or accelerated exsanguination or further destabilized a patient with a severe head injury. an upper spinal cord transection, diaphragm and lung laceration, haemothorax, or pneumothorax—which is difficult to identify in an autopsy—seem to have led to respiratory failure in some cases. Traumatic brain injury, multiple injuries like exsanguination, or a combination of the two seem to be the cause of death in most cases.

4.2. Pedestrians

For pedestrians, injuries are usually divided into primary, secondary, and tertiary injuries. Primary ones occur at the first contact with the vehicle, like the bumper. Secondary ones happen because of the second contact with the vehicle, such as the windscreen. Tertiary ones are caused by the fall onto the street. The type of injury also very much depends on the speed of the collision. In low-speed accidents (up to 20 km/h), the patient is found in front or to the side of the vehicle or is run over. In medium-speed accidents (20–60 km/h), the pedestrian hits the hood of the car or its windshield. In high-speed accidents (60–100 km/h), the pedestrian is thrown into the air. In high-speed accidents, the contact with the windshield and consequent fall onto the ground often cause severe head injuries [14,15]. The results of this analysis showed that around 4 out 5 pedestrians had cranial fractures and 95% had traumatic head injuries. Subarachnoid hematomas were found in 80% of pedestrians involved in fatal incidents. Subdural and intraventricular hemorrhages were both found in 60% of pedestrians. This was the highest rate among all road users, and only cyclists had a similar amount of these injuries. Additionally, other studies show that pedestrians have the highest incidence of traumatic brain injuries [16,17]. Fifteen percent of cervical injuries, on the other hand, is the lowest rate among all road users. Spinal cord injuries, including transections, were found in 28% of dead pedestrians, and 7.5% involved the C1–C5 vertebrae. Thoracic injuries were a little less common than in car occupants (90% vs. 98%). Approximately, the study found rates of 18 percent for left and right lung lacerations, 30% for pericardial ruptures, and 12.5% for ruptures of the heart. Thoracic aorta lacerations occurred only half as often as in car occupants (20% vs. 40%). Abdominal injuries (55%) in pedestrians were less common than in fatal car accidents (73%). Liver lacerations occurred in 30% and splenic in 17.5% of cases; both values were the lowest among all road users. Approximately 38% had a fractured pelvis. Upper extremity fractures were much less common than lower ones (28% vs. 43%). Overall, it can be said that traumatic head injuries were more common in pedestrians than in car occupants, with thoracic injuries occurring a little less and abdominal injuries occurring far less. In pedestrians, traumatic brain injuries were particularly prevalent, but again, multiple injuries seemed to be the cause of death in most cases.

4.3. Motorcyclists

Seventy percent of motorcyclists sustained traumatic head injuries. This was the lowest incidence among all road users, and one of the reasons seemed to be the protective helmets. Neurocranial fractures at the top were sustained in 15% of the cases. Fractures at the base were found in 45% of fatal motorbike accidents, three times more often than fractures at the top. The helmet seems to be responsible for the proportionally low number of the top fractures but high number of base fractures of the neurocranium in motorcyclists. A motorcycle helmet protects the top of the skull effectively but has little impact on the base of the skull [18]. Forty-eight percent of motorcyclists sustained cervical injuries, which was highest among all road users. In 40% of all motorbike fatalities, spinal cord injuries were found. Twenty-five percent had an upper cervical spinal cord injury including transections, which was more than any other group. The weight of the helmet might cause extra stress on the neck during the incident [19]. Thoracic (95%) and abdominal (70%) injuries were nearly as high as for car occupants. Left and right lung lacerations and pericardial ruptures were found in 22.5% of motorcyclists. Thoracic aorta lacerations occurred in 35% of the cases, the second-highest rate among all road users after car occupants. Thus, it seems that high-velocity accidents cause more of these injuries. Ruptures of the heart occurred only in 8% of cases, and diaphragmatic lacerations occurred in only 5% of the cases. Liver lacerations were found in 55% of the cases and splenic ones in 32.5% of the cases. Ruptures of the heart occurred only in 7.5% of the cases, while diaphragmatic lacerations were in only 5% of the cases. Motorcyclists were the only category in which the number of upper extremity fractures was higher than that for lower ones (38% vs. 33%). Pelvic fractures were at 18%, the lowest rate among all groups.

Motorcyclists had a very similar pattern of injuries to car fatalities, with a predominance of head, thoracic, and abdominal injuries. Only ruptures of the heart [20] and pelvic fractures were less common in motorcyclists than in car occupants, and upper cervical spinal cord injuries occurred much more. The cause of death was again mainly due to traumatic head injuries, multiple injuries, or a combination of the two. Another study suggested that 51% of motorcyclists die for craniocerebral injuries and 37% die from multiple injuries [11].

4.4. Cyclists

The rate of head injuries was extremely high (93%) and nearly identical to that of pedestrians. Like motorcyclists, cyclists sustained more fractures of the base (70%) of the neurocranium than the top (37.5%). Thirty-eight percent sustained cervical injuries, and 15% had C1–C5 spinal cord injuries; both values were at the top, being second place among all road users after motorcyclists. Thoracic and abdominal injuries were a little more common in cyclists than in pedestrians (93% vs. 90% for thoracic and 60% vs. 55% for abdominal injuries). Pericardial ruptures had the highest rate, being 37.5% among all road users, while thoracic aorta lacerations had the lowest rate with 15%. Liver lacerations were found in 37.5% of bicycle fatalities, and splenic lacerations were found in 20%. Thirty-three percent had fractures of the pelvis. Upper extremity fractures (18%) were less common than lower ones (30%), like in pedestrians. Overall, cyclists sustained fewer fractures in their extremities than pedestrians. It seemed that cyclists were often hit by cars at the level of the lower limbs more often than pedestrians, causing fractures. In cyclists, like pedestrians, traumatic brain injury, as well as multiple injuries or a combination of the two, seemed to be the cause of death in most cases. In an analysis of 137 cyclists in Berlin who died from 2000 to 2009, 51% died of traumatic head injuries, and 35% died from multiple injuries. Seventy-seven percent of the 137 cyclists did not wear a helmet, and 65% died on the scene [10]. A study from Sweden suggested that 91% of fatally injured cyclists could be saved with known techniques. Forty-six percent of cyclists which did not wear helmets could have been saved just by wearing a helmet [21].

4.5. Truck Drivers

As truck accidents are quite rare, the sample size was only 20 units, half as large as the other groups. That made this group statistically less robust. The injury pattern was nearly identical to the one for car fatalities. High incidences of head (80%), thoracic (95%), and abdominal (75%) injuries were found in truck fatalities. The cause of death was again traumatic head injury, multiple injuries, or a combination of the two. Subarachnoid hematoma (60%), liver lacerations (50%), and pelvic fractures (50%) were the most frequent injuries observed in this group of road users. The upper and lower extremities were similarly involved.

As for spinal cord injuries, traffic accidents were the leading cause in the United States at 48% [22–25]. An Italian study showed that falls accounted for 41% of spinal cord injuries, and traffic accidents accounted for 34% [26]. Patients with spinal cord injuries at the level C1–C3 had a 6.6-fold increased risk of mortality and 2.2-fold risk if they were injured at the C4–C5 level compared with patients with thoracic spinal cord injuries or lower [27].

Spinal cord injuries and transections can not only cause severe disabilities like paraplegia and tetraplegia, but they can also be a cause of death. The diaphragm is innervated by the phrenic nerves, which originate from the spinal roots of C3–C5. Thus, a spinal cord transection at the level of C3–C5 or above can cause respiratory failure. If bystanders do not start basic life support, this injury will lead to cardiac arrest within minutes, and emergency medical services often arrive too late. spinal cord injuries above C5, including transections, were found in all road users. The most affected group was one of the motorcyclists, in which one in every four cases (25%) sustained such an injury. This injury was also found in 15% of cyclists. A literature review also confirmed that motorcyclists are most at risk for severe spinal cord injuries, particularly upper cervical injuries, among all road users [28,29].

Concerning traumatic aortic ruptures, in Japan, 64% of events occurred in traffic accidents. Eighty-five percent of patients with an aortic rupture exsanguinated and died on the scene [30]. In this analysis, rupture of the thoracic aorta was found on average in one in every four road users. Incidence was the lowest in cyclists at 15%, the highest in motorcyclists at 35%, and in car occupants, it was 40%. These were also the two groups that sustained most thoracic and abdominal injuries. Other large vessel lacerations were far less common. Laceration of the inferior vena cava was the second-most common injury. One reason for this may be the anatomy of the thoracic aorta. Due to the branching off of the brachiocephalic trunk, the left common carotid artery and the left subclavian artery, especially at the aortic arch, are subjected to forces pulling in different directions in the case of an incident. Aortic ruptures are more common in deceleration accidents with a large change in velocity, leading to huge forces acting on the body and internal organs and their displacement [31]. The two main reasons for aortic rupture seem to be bending and shearing forces. Bending occurs when the aorta is bent over the left pulmonary artery and left bronchus, while shearing happens because the deceleration (and therefore displacement) differs between the aortic arch and the descending aorta [31]. In this analysis, nearly all ruptures of the aorta (98%) occurred at the level of the thoracic aorta, most of them (58%) being at the isthmus just after the branching off of the left subclavian artery, 21% occurring at the ascending aorta, and 17% occurring at the arch. In addition, other studies showed that 55–65% of aortic ruptures occur at the isthmus. However, only in 10–14% of cases did the arch or descending aorta seem to be affected [30,31].

Finally, we must acknowledge some limitations of this study. Regarding thoracic injuries, which occurred in nearly all road user victims, it is important to consider an overestimation due to injuries sustained during resuscitation, such as rib fractures. There are also certain life-threatening injuries, which can easily be missed or not even evaluated in an autopsy like pneumothorax, minimal spinal cord injuries, bone infringements or small fractures, traumatic brain apnea, and basilar artery ruptures.

5. Conclusions

Most of the victims of RTCs were male drivers, and the age group most affected was people in their twenties to forties. From the autopsy reports, car and truck occupants, as well as motorcyclists, had a higher proportion of multiple injuries than pedestrians and cyclists. Pedestrians and cyclists instead died more often because of traumatic head injuries. These findings may be of great relevance to clinicians, orthopedists, and rescue teams who have to provide aid to victims of RTCs. Indeed, being aware of which injuries are most likely to have to be dealt with optimizes the chance of success. Moreover, the finding that more than half of all victims died immediately after the incident may give rise to some reflections about the factual safety of vehicles and the attention of drivers when driving. Finally, in such lethal cases, the information concerning the type of reported injuries would have been lost if the autopsy had not been performed. Therefore, forensic medicine is confirmed as a pivotal discipline for the protection of public health, allowing the collection of relevant information on which to base prevention strategies for the benefit of living patients.

Author Contributions: Conceptualization, methodology, and original draft preparation, S.T.; methodology, data curation, and original draft preparation W.R.; writing—review and editing, C.C.; validation and supervision, F.C. All authors have read and agreed to the published version of the manuscript.

Funding: The authors received no financial support for the research, authorship, or publication of this article.

Institutional Review Board Statement: This article does not contain any studies with living human participants performed by any of the authors. All the studies conducted followed the guidelines provided by legislation and the National Bioethical Committee.

Informed Consent Statement: The authors declare that the investigating magistrate authorized all the forensic investigations performed in this study in accordance to Italian law.

Conflicts of Interest: The authors declare no conflict of interest.

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