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Research Article

Road Traffic Related Injury Severity in Truck Drivers: A Prospective Medical and Technical Analysis of 582 Truck Crashes

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Abstract

Background: While cyclists and pedestrians are known to be at significant risk for severe injuries when exposed to road traffic accidents (RTA) involving trucks, little is known about RTA injury risk for truck drivers.

Objectives: The aim of this study was to analyze the injury severity in truck drivers following RTAs.

Patients and Methods: Our local accident research unit prospectively documented 43000 RTAs involving 582 trucks between 2000 and 2011. Injury severity, including the abbreviated injury scale (AIS) and the maximum abbreviated injury scale (MAIS) were analyzed. Technical parameters (e.g. delta-v, direction of impact), the location of accident, and its dependency on the road type were also taken into consideration.

Results: Thirteen percent (77/582) of truck drivers were injured. Extremities were found to be at highest risk of injury with the lower extremities (36x) being injured most severely (10x: AIS 2 and 3). Death occurred only after collisions with other trucks, and severity of injuries increased with an increased speed limit. The maximum abbreviated injury scale was higher in the crash opponents (56x MAIS $\geq$ 3) compared to the truck drivers (8x MAIS $\geq$ 3). Overall, 82% of the crash opponents were injured.

Conclusions: The safety of truck drivers is assured by their vehicles, the consequence being that the risk of becoming injured is likely to be low. However, the legs especially are at high risk for severe injuries during RTAs. This probability increases in the instance of a collision with another truck. Nevertheless, in RTAs involving trucks and regular passenger vehicles, the other party is in higher risk of injury.

Keywords: Trucks, Abbreviated Injury Scale, Trauma

1. Background

Mortality after incidents involving trucks has recently decreased. However, the occurrence of fatal road traffic accidents (RTAs) still involves thousands of people every year. In 2011, 3593 people died in accidents involving trucks or busses in the USA (1). Other road users, such as cyclists, are also at high risk of severe injuries (2, 3). Most of truck drivers have to fulfill strict timetables and are therefore neglecting their fatigue and a lack of concentration (4, 5). In 2003 a questionnaire amongst truck drivers was performed. Of the participants, 20% reported to be dissatisfied with route planning and scheduling (6). Moreover, it was shown that the driving performance of truck drivers is sleep dependent. Unfortunately, studies revealed that truck drivers often do not recognize their sleepiness, or, if they do, continue driving regardless (7). In a multinational survey, almost 30% of truck drivers admitted to having had at least one near miss experience in the last three months due to fatigue (6). The growing rate of drive control cards is starting to decrease the number of tired truck drivers on the road. However, experience has shown that the drive control cards are often neglected. Therefore, RTAs involving trucks still happen frequently. Detailed analysis of crashes showed that they range from simple front crashes to rollovers, especially when towing trailers (8). It has been published that truck drivers have a high lifetime risk of becoming injured due to a traffic incident. Commercial truck drivers are seven times more likely to have an accident related death when compared to the average population of the U.S. (9). The risk of truck drivers suffering serious injuries after a collision is high. Occupants in single vehicle RTAs are at higher risk of serious injuries than in multi vehicle accidents (10, 11). In single and multi vehicle RTAs truck drivers injury severity was partially dependent on the age of the truck driver as well as the number of vehicles involved in a collision: elderly truck drivers ($\geq$ 50 Years) had a 5.4% increased risk of fatality in single vehicle RTAs; however fatality was decreased by 7.5% with multi vehicle RTAs. Authors suggest that this is due to longer reaction times on the one hand, and more driving experience and cautious driving on the other (12). Reasons for RTAs involving trucks are multifactorial. They include chronic illness, tiredness/lack of concentration, intoxication, speed and time (8, 13, 14). The effect of the individual driving style is still being considered (13, 15, 16).

Moreover, a drivers' work/live in generally unhealthy environments, with a dearth of healthy options, and a resulting high prevalence of associated diseases can be found. This is related to both the occupational framework and sometimes personal risk-taking behavior patterns. Nevertheless, there is a substantial deficit of prevention and medical care (the latter especially) on the road (17).

Although frequency of RTAs involving trucks has previously been analyzed well, information as to injury severity following RTAs is rare (8, 18). Particularly, injury severity with regard to the injury pattern is of great importance as this might help for early optimal assessment of injured truck drivers during rescue. Moreover, this could help to modify safety precautions, e.g. construction of driver's cabin.

The objective of our study, therefore, was to analyze injury severity and location of injury to truck drivers following RTAs in Germany. Additionally, injury severity of second participants was analyzed.

2. Objectives

The objective of this study was to analyze the injury severity in truck drivers following RTAs.

3. Patients and Methods

3.1. Study Population

The study was approved by the local ethical committee and follows the ethical standards of the Helsinki declaration of 1975, as revised in 1983. Informed consent was obtained from every single objective included.

A truck was defined as a vehicle weighing 7 tons or more (see: driver license type C in the European Union).

3.2. Assessment

Technical in-depth crash investigations, in combination with medical data analysis, were performed by specially trained documentation personnel from our local in-depth accident research unit as a part of the trauma department of the Hannover Medical School. This documentation crew is notified by police dispatchers immediately after an accident and often arrives on the scene simultaneously with the rescue personnel. Investigation of the crash and clinical injury documentation is performed on site. This case report is then completed at the hospital, where all of the injured victims are taken, with proper documentation of X-ray examination, injury type and severity. The monitoring includes demographic data, the area of collision, environmental circumstances, and injury patterns. Furthermore, it includes specific outcome and severity scores, such as abbreviated injury scale (AIS), injury severity score (ISS) and maximum abbreviated injury scale (MAIS) (19, 20).

3.3. Data Evaluation

We analyzed the prospectively collected database for a consecutive series of RTAs involving trucks weighing $\geq$ 7 tons and analyzed the injury patterns of the truck drivers and also crash opponents, which were documented using the AIS 2005 between 2000 - 2011 (21).

Information about both victims, primary type of vehicle and injury severity using the MAIS, was also included. For objective presentation of injury severity we focused on the AIS and MAIS as these scores are simple tools to gauge the extent of injury. This method is the gold standard in accident research (22, 23).

Location of crash rural or in town, as well as the type of street "-" is taken into account as speed and driving differs depending on these factors.

A technical analysis provides information as to the speed, the delta-v, direction of impact, and the side of contact of the involved vehicles.

3.4. Statistical Analysis

Statistical analysis was performed using SPSS 20 for Windows (IBM).

4. Results

4.1. General Information, Location and Crash Opponents

582 truck drivers were included in our study. 571 truck drivers were male and seven were female. The gender was unknown in four cases. Different types of trucks were included: 459 trucks weighed > 13t, 89 weighed 7.5t to 13t and 8 weighed 7t to 7.5t. In 26 cases no information as to the size of the truck was available. Of these, 373 (64%) crashes were rural, 209 (36%) in a town. Of the rural accidents, 257/373 occurred on freeways, the others on rural roads or federal highways.

The crash opponents were mostly cars (n = 410, 70%) followed by trucks (n = 141, 24%). A small number of trucks drove into other objects such as traffic lights etc. (n = 31, 5%).

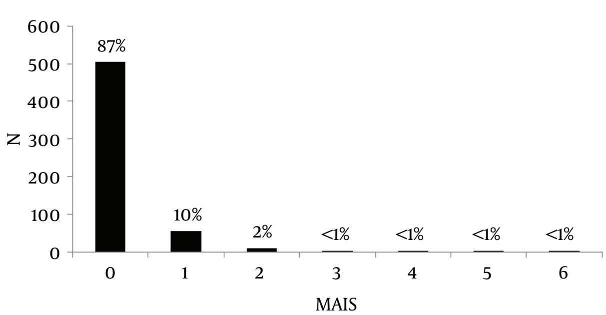
4.2. The Abbreviated Injury Scale of Truck Driver

The AIS of the truck drivers are presented in Tables 1 and 2. Most injuries involved the legs (n = 36) and secondly the arms (n = 32), the least common were injuries involving the thorax (n = 0). The most severe injuries involved the legs (AIS 2 and 3: 10x), the head (AIS 6: 2x; AIS 2: 4x) and the arms (AIS 2 and 3: 8x). While most truck drivers were male, only 1/7 femal truck driver was injured (AIShead 1).

4.3. The Maximum Abbreviated Injury Scale for Truck Drivers

Out of the 582 truck drivers, 77 were injured, indicating 13% of the cohort. MAIS 0 was found in 505 (87%) cases, 56 (10%), 11 (2%), 4 (1%), 1 (< 1%), 2 (< 1%) and 3 (< 1%) cases did present with MAIS 1 - 6 respectively. Results are visualized in Figure 1. MAIS was higher in accidents on freeways compared to other streets. MAIS 3 - 6 was found in 8 cases (3%), whereas the highest MAIS on other streets was 3 (2x). The MAIS of the truck drivers was higher when involved in collisions with other trucks (MAIS 3 - 6: 9x) compared to objects or cars where the highest MAIS to be found was 3 (1x). Death only occurred after collisions with other trucks.

Figure 1. The Maximum Abbreviated Injury Scale for Truck Drivers



N, amount of patients.

Truck drivers were at a higher risk of severe injuries when involved in crashes on freeways (MAIS 6: 3x), compared to other roads, where no death occurred. MAIS 4 to 6 was only found in truck drivers of vehicles weighing more than 13t.

4.4. The Maximum Abbreviated Injury Scale of Crash Opponents

No other road users were involved in 33 of the 582 RTAs (6%). Of these, 31 RTAs involved stationary objects, 2 involved commercial vehicles (stationary). Only a small number of crash opponents did not suffer any form of injury (n = 60; MAIS 0). In fact, most of the people were injured (n = 450/549; 82%). 315 (57%) suffered from minor trauma (MAIS 1), 79 (14%) suffered from moderate injuries

Table 1. [Part 1] The Abbreviated Injury Scale of Truck Drivers: Subsets Are Presented for Different Body-Regions[a]

AIS	Specification AIS	N	Injured (x/582)
Head			28
	0	554	
	1	22	
	2	4	
	3	0	
	4	0	
	5	0	
	6	2	
	9	0	
Neck			23
	0	559	
	1	22	
	2	0	
	3	0	
	4	0	
	5	1	
	6	0	
	9	0	
Thorax			0
	0	582	
	1	0	
	2	0	
	3	0	
	4	0	
	5	0	
	6	0	
	9	0	
Abdomen			6
	0	576	
	1	1	
	2	3	
	3	0	
	4	0	
	5	0	
	6	0	
	9	2	

Abbreviations: AIS, abbreviated injury scale; N, amount of patients.
[a]The number of patients being injured are presented in every body-region related subset.

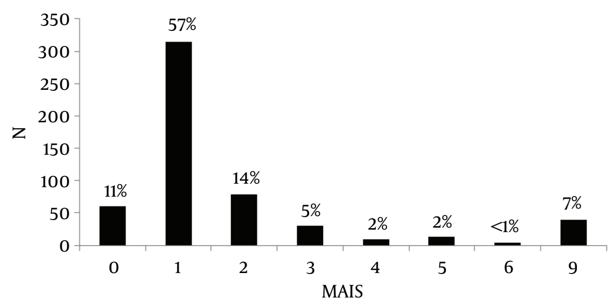
Table 2. [Part 2] The Abbreviated Injury Scale of Truck Drivers: Subsets Are Presented for Different Body-Regions[a]

AIS	Specification AIS	N	Injured (x/582)
Pelvis			6
	0	576	
	1	2	
	2	2	
	3	0	
	4	2	
	5	0	
	6	0	
	9	0	
Arms			32
	0	550	
	1	24	
	2	6	
	3	2	
	4	0	
	5	0	
	6	0	
	9	0	
Legs			36
	0	546	
	1	26	
	2	4	
	3	6	
	4	0	
	5	0	
	6	0	
	9	0	

Abbreviations: AIS, abbreviated injury scale; N, amount of patients.
[a]The number of patients being injured are presented in every body-region related subset.

(MAIS 2). Five percent (30) of road users sustained serious trauma (MAIS 3), and 9 (2%) severe injuries (MAIS 4). 13 (2%) participants were critically injured (MAIS 5), and 4 (< 1%) people showed maximum severity of injury that could not be treated (MAIS 6). MAIS 9 was documented for 39 people. Results are presented in Figure 2.

Figure 2. The Maximum Abbreviated Injury Scale for Second Participants



N, amount of patients.

4.5. Comparison of the Maximum Abbreviated Injury Scales

On average, the opponents were more severely injured (Figures 1 and 2). While only 13% of truck drivers were injured, 82% of the second party occupants suffered trauma, given that most second participants were car drivers.

4.6. Technical Analysis

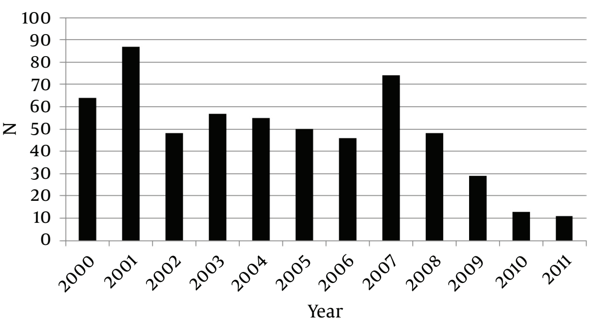
Technical data were provided for 554 of 582 crashes. Of these, 350 happened in rural areas, 208 of the RTAs took place in town. Rural, the mean impact velocity (delta-v) could be calculated in 350 accidents. It was 7.74 km/h ± 10.62 km/h. The mean impact velocity on freeways was 9.29 km/h compared to 4.44 km/h on other rural roads ($P < 0.001$) with a higher MAIS of the truck drivers on freeways (see above). In 204 urban crashes, technical data were recorded. The mean impact velocity was 4.60 km/h ± 7.30 km/h; this was significantly lower than in rural RTAs ($P < 0.001$).

MAIS was highest after frontal collisions (MAIS 6: 2x), followed by collisions to the rear, with MAIS 2 the highest being observed once only. 14 rollovers could be included with the highest MAIS being 3.

4.7. Time Analysis

A significant decrease of crashes involving trucks was detected during the study period which is presented in Figure 3. There was a decrease from 64 crashes in 2000 to 11 crashes documented in 2011. However, the MAIS did not change significantly during 2000 and 2011, highest values being 5, 5, 6, 3, 6, 4, 2, 2, 6, 2, 1 and 0. Crashes occurred during day, night and twilight in 401, 135 and 46 cases. No significant difference of injury severity analyzing the MAIS could be found dependent on the daytime (P = 0.456)

Figure 3. Number of Truck Crashes Included Into the Study Per Year



N, amount of patients.

5. Discussion

Within this study we were able to show that lower extremities were of highest risk of severe injury for truck drivers and that the MAIS was highest after frontal collisions. It is reasonable that the risk of severe injury significantly increases in the case of, and proportionately to, the deformation of the driver's cabin. However, the deformation was not analyzed in this study. The opponents did present higher MAIS levels. Truck drivers only died after collisions with other trucks. Nevertheless, truck drivers overall are at a relatively low risk for severe injuries. Charbotel et al. analyzed the injury severity of truck drivers and described it using the injury severity score (ISS). 13% of truck drivers did present with injuries being classified 9 $\leq$ (24). These results support our findings.

As indicated by the AIS, the risk of injury is different for the various body regions. Upper and lower extremities are in higher risk for trauma and were injured in 6.2% and 5.9% of cases respectively with the AIS being highest in the lower extremities followed by arms and the head (Tables 1 and 2). Our results suggesting that legs have the highest risk for severe injury were also published by Zinser and Hafner, who found that 65% of in-patient truck drivers had been involved in RTAs and suffered from injury to the lower extremities (25). This is most likely related to the missing crush-collapsible zone.

The abbreviated injury scale has been used before to describe severity of injuries in truck drivers. McKnight et al. analyzed 239 rollover crashes; 51 passengers were also included in this analysis. In total, 21 collisions proved to be fatal, 4 suffered from harm classified as AIS 4 or 5, and AIS 2 or 3 was documented in 42 cases. Minor injuries classified AIS 1 were documented in 172 cases, and 51 patients did not present any injury. As found in our study, the majority suffered from minor to moderate injuries, whereas the amount of passengers for each anatomical AIS subset is unknown (8).

In Germany, trucks are usually permitted to drive with a maximum speed of 80 km/h. This has to be taken into account when looking at injury severity levels. Speed seems to be an indicator of the extent of trauma as MAIS was higher in truck drivers who crashed on freeways where the speed limit is higher compared to streets in town. This was proven previously (8).

RTA injuries depend on a range of variables, and thus a wide range of outcomes are possible. As truck drivers spend most of their time in their cabins they carry many utensils that are of potential risk of flying around and potentially harm the driver during an accident. Moreover truck drivers tend to ignore mandatory seat belt wearing more often than car drivers.

While in our study, death only occurred after collision with other trucks, no severe injuries were noted after collisions with cars. This is reasonable as the height of impact is low. Moreover, deformity of the passenger cabin mostly occurs below the sitting position of the truck driver. Therefore the passenger cabin assures good protection in truck-car related RTAs. In contrast, the risk for severe injury is increased for car drivers (26, 27).

Overall, 0.5% of the truck drivers died which is comparable to already published data (0.6%) (28). However, mortality is known to be increased by 8.8% in accidents involving rollovers. In the described study population no death occurred after a rollover (8).

the Maximum Abbreviated Injury Scale was highest after frontal collisions, which can be related to the missing crush-collapsible zone again and was already published previously (28).

Analysis of technical parameters clearly indicated relatively low impact energies despite the fact of the relatively high inertia of vehicles. However, this simple observation might explain the low injury severity in truck drivers except for RTAs involving rear end collisions or roll-overs. Research on vehicle crashworthiness was able to demonstrate injury severity as being directly proportional to opposing vehicle mass. However, we were able to confirm these findings, vice versa, for truck drivers. Conclusions showing that increased speed is related to increased injury severity are not a new finding.

In our study cohort, most crashes occurred during daytime. The same was found by Charbotel et al. who found 87% of truck crashes to happen between 4 am and 6 pm in a French population (24).

We were unable to make a statement on driving times. We rely on legal documents. Medical documents of this relatively unhealthy population were not investigated.

To the best of our knowledge, there are no other studies that have specifically analyzed the AIS and MAIS of truck drivers. This is the first detailed description of injury severity of truck drivers involved in collisions. The number of investigated crashes is big, and that is unique. It is not debatable that behavioral interventions are needed to improve road safety.

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Footnotes

Authors' Contribution: Study concept and design: Sebastian Decker; acquisition of data: Dietmar Otte; analysis and interpretation of data: Sebastian Decker, Stephan Brand; drafting of the manuscript: Sebastian Decker, Carl Haasper, Stephan Brand; critical revision of the manuscript for important intellectual content: Christian Walter Muller, Carl Haasper, Mohamed Omar; statistical analysis: Sebastian Decker; administrative, technical, and material support: Dietmar Otte, Christian Walter Muller; study supervision: Dietmar Otte, Christian Krettek.

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