

The Number And Structure Of Road Users With Life-Threatening Injuries

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Abstract – A total survey of road traffic accidents involving most severely injured, defined as sustaining a polytrauma or severe mono-trauma (ISS > 15) or being killed, was conducted over 14 months in a large study region in Germany. Data on injuries, pre-clinical and clinical care, crash circumstances and vehicle damage were obtained both prospectively and retrospectively from trauma centers, dispatch centers, police and fire departments. 149 patients with a polytrauma and eight with a severe mono-trauma were recorded altogether. 22 patients died in hospital. Another 76 victims had deceased at the accident scene. In 2008, 49 % of patients treated with life-threatening injuries were car or van occupants, 21 % motorcyclists, 18 % cyclists and 10 % pedestrians. Among fatalities at the scene, vehicle occupants constituted an even larger portion. The number of road users with life-threatening trauma in the region was extrapolated to the German situation. It suggests that 10 % among the “seriously injured” as defined in national accident statistics are surviving accident victims with a polytrauma or severe mono-trauma.

INTRODUCTION

The progresses in vehicle safety and medical treatment of life-threatening trauma have contributed to a steady decline of road traffic fatalities in many western countries. Traffic safety has been measured almost exclusively by these numbers until recently. Lately, however, most severely injured, but surviving victims of accidents have been receiving increased attention among road safety stakeholders in Germany and other countries. Research in this field indicates that the number of severe traumata in survivors does not decline at the same rate as can be observed for the number of fatally injured. The German Highway Research Institute (Bundesanstalt für Straßenwesen BAST) conducted a pilot study which evaluated different sources and tried to determine the number of road traffic victims suffering from long-term or permanent disabilities, but could not notice any decrease of case numbers over a nine-year period [1]. The study included also injuries which are not potentially life-threatening, but can nevertheless lead to long-lasting functional impairments, e. g., complex fractures of the foot or hand. Research in the field of trauma surgery, on the other hand, often addresses epidemiology and treatment of severe multiple injuries, sometimes also termed “polytrauma”, which present a major challenge in emergency care [2, 3]. Undoubtedly, these most severe injuries not only pose a considerable threat to vital functions, but are often associated with long-lasting consequences if the patient survives [4]. Most trauma studies are not limited to motor-vehicle crashes as injury causes, but include falls from great height, occupational or leisure accidents as well. Large-scale studies that provide data on most severe injuries and detailed information about the circumstances of crashes are rare, at least in Germany [5, 6]. Estimates of the incidence rate of most severe injury patterns caused by road traffic accidents are few and the results differ considerably, depending on the criteria for recruited patients [3, 6].

OBJECTIVE OF STUDY

The present research work aims to increase the knowledge on most severely injured in addition to analyses of national road accident statistics or medical registers, like the Trauma Register of the German Society for Trauma Surgery (DGU) [6, 7]. For this purpose, a complete accident survey involving patients with life-threatening trauma from road traffic accidents and all victims deceased at the scene was carried out in a large study region. The objective was not only to determine injury

patterns and severities, but also to distinguish between the types of road users and to document general accident circumstances, crash characteristics and the use or activation of occupant protection devices like seat belts and air bags.

METHODOLOGY OF STUDY

The study region in southern Germany is defined by the administrative boundaries of six counties and two large cities with a total population of approximately 1.32 million. Both in relation to the road infrastructure and the accident situation regarding injury severity and road users, the area represents the entirety of traffic accidents involving personal injury in Germany well [8]. The three trauma centers in the region are the primary target hospitals for patients with life-threatening multiple injuries. Patients from outside the study region are treated here, too, whereas few victims of incidents occurring within the study region may be transported to other, more remote hospitals under certain conditions. Only patients who were severely injured in a traffic accident that occurred in one of the six counties or two cities were included in the study material to allow comparison with the official road traffic accident figures for the area. Data were collected over a 14-month period lasting from November 2007 until December 2008.

Patients for the study were identified in several steps: data from rescue dispatch centers, sometimes supplemented by information obtained from local media reports, provided first indication of potentially relevant cases and the target hospitals where the patients had been treated first. The respective hospitals reviewed their data to identify the suspected individuals by date and time of hospital admission and accident location as reported by rescue personnel. Injuries that matched the criteria were documented in a special reporting form, coded according to AIS 98 and the Injury Severity Score ISS calculated. Injury patterns with an ISS of 16 or higher were deemed to be life-threatening. Where two or more body regions (see Fig. 1) were affected such pattern was defined as a polytrauma. If the injuries were limited to only one body region they were defined as a severe monotrauma. Patients with injury severities below ISS 16 were excluded from evaluation except for those who deceased within 30 days after the accident. Data on patients who were transported to trauma centers outside the region, mostly by helicopter, were researched, too, where possible.

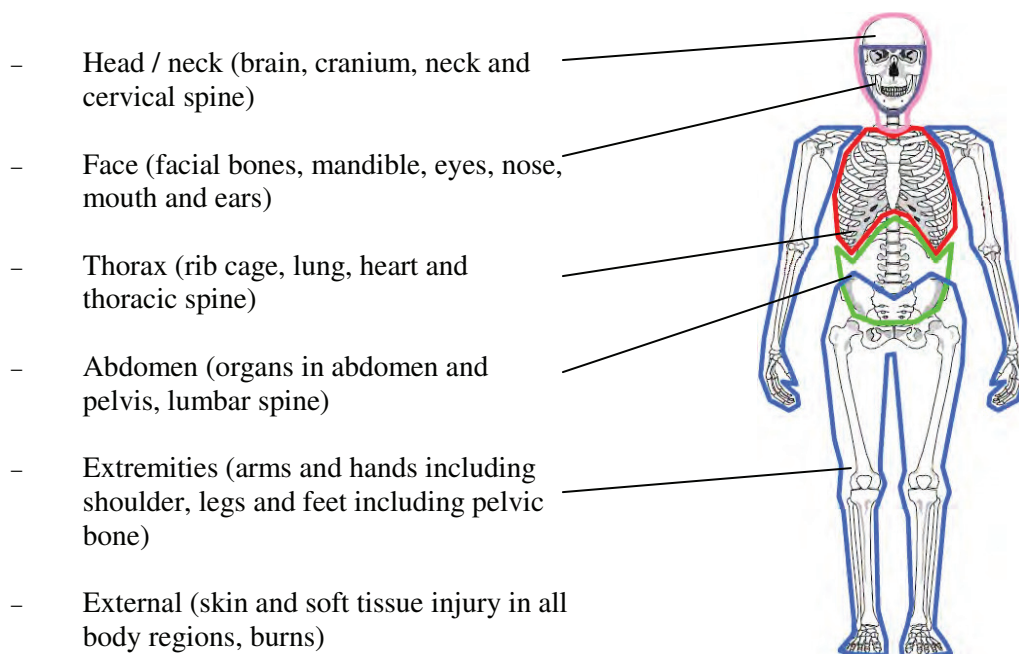


Figure 1. Definition of body regions for ISS calculation (acc. to [7])

With information about the time and location of the accident, the police or public prosecutor's offices, respectively, were contacted and requested to provide the accident report, photos taken at the scene or any accident reconstruction report. In addition, fire departments responsible for technical rescue in the area were asked to photograph vehicle damage at the scene right after the acute phase of rescue. They also documented which air bags in a car had deployed and the rescue operations to extricate occupants. The single data sets were sanitized by the contributing partners and then matched and linked by the study coordinator via characteristics like vehicle type, seating position, age and gender. The combined retrospective and prospective approach to collect data anonymously was described in more depth in an earlier paper [8]. Victims who deceased before they arrived at a hospital were included in the study as well, but usually lack detailed diagnosis unless an autopsy is performed. Obviously, a life-threatening injury can be suspected in such cases, too.

STUDY MATERIAL

149 victims of road traffic accidents with life-threatening trauma who were treated in trauma centers were identified during the complete 14-month study period. Eight of them suffered a severe mono-trauma whereas the rest sustained severe multiple injuries, i. e., a polytrauma. 22 of them died in hospital, some of them within minutes after arriving in the emergency room. Except for two cases where death occurred before diagnostics could be performed, all patients could be described with their injury patterns. All surviving patients were included in the national statistics and counted as "seriously injured", i. e., belonged to the category of in-patients for at least 24 hours. 76 road users more died at the scene of the accident, either before pre-clinical measures could be applied or during rescue or resuscitation attempts.

Fig. 2 shows the number of patients treated in hospitals and the number of fatalities at the scene during the twelve months of 2008. The latter category includes two cases where road users did not sustain life-threatening injuries according to the above definition, but deceased in hospital after a few days anyhow. Health complications following the actual accidental injury were reported as the cause of death. The chart also shows a small number of fatalities which were not included in the national road traffic accident statistics, in most cases because a suicide was presumed.



Figure 2. Structure of most severely and fatally injured in 2008

The share of types of road users differs, depending on whether they were transported to a hospital with life-threatening injuries or deceased at the accident site (see Fig. 3 and Fig. 4). Occupants of passenger cars represent the largest share in both groups, but are even more prominent where death occurred at the scene. Occupants of light vans (up to 3.5 tons of gross vehicle mass) are displayed as a separate group. This vehicle category does not exist in German accident statistics where such vehicles are either subsumed under passenger cars or goods vehicles, depending on their registration. Small

commercial vehicles which are technically derived from small or compact car models are counted as passenger cars for the purpose of the study. Only one driver of a larger truck who was killed when his vehicle rear-ended a semi-trailer combination is contained in the study material. Cyclists and motor-cyclists each represent a considerable portion of the severely injured and the fatally injured. The shares of pedestrians among road users treated in a hospital and fatalities at the scene are alike.

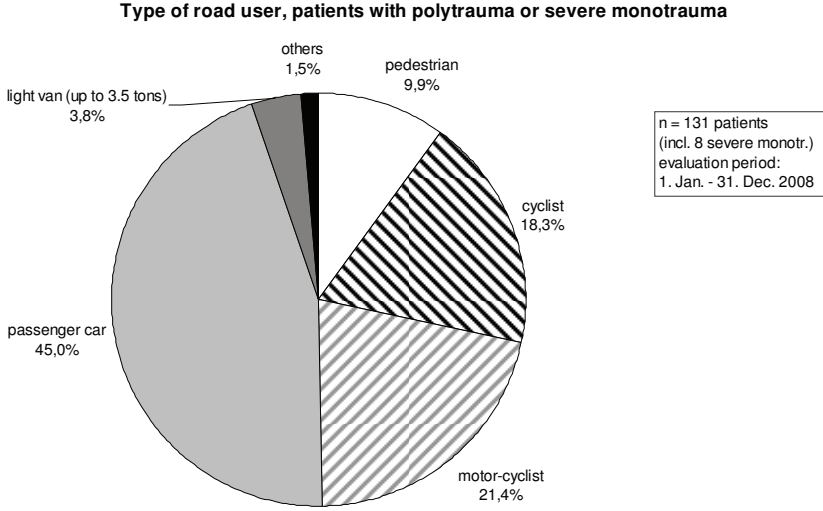


Figure 3. Road users with life-threatening injuries treated in hospitals, 2008

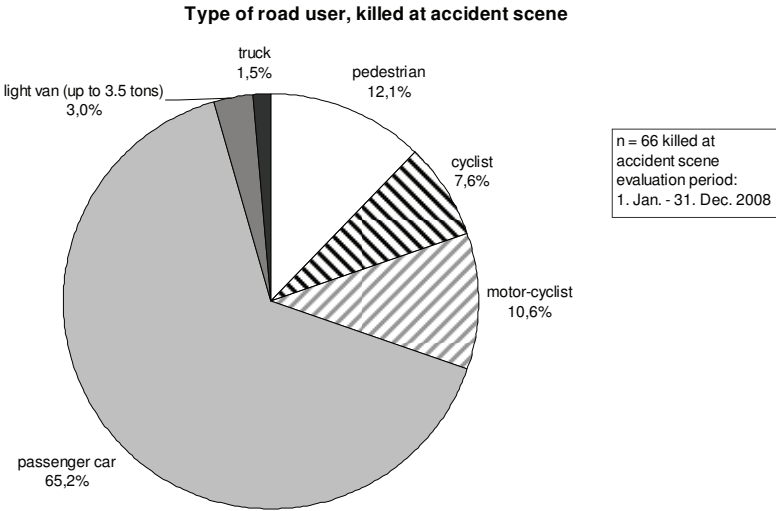


Figure 4. Road users killed at accident scene, 2008

RESULTS

The evaluation is based on all incidents collected over 14-months in which road users of the respective type (pedestrians, cyclists, motor-cyclists and motor-vehicle occupants) sustained a life-threatening trauma (149 cases) or died before being transported to a hospital (76 cases). The results are given by the type of road user in the following.

Pedestrians

16 pedestrians received life-threatening injuries, almost all of them when colliding with a passenger car or light van, and were taken to a trauma center. All of these patients survived. Two more patients were treated in a hospital after they had fallen from moving trailers on which they had been riding. Both suffered most severe brain injuries and died a few days later. These two cases are presented here together with pedestrians who sustained a polytrauma (see Figure 5).

Furthermore, nine pedestrians died at the accident scene due to the severity of their trauma. One more deceased in hospital after she was thrown to the ground by a car at low speed and had suffered several fractures of the lower extremities, but no life-threatening injury pattern according to the definition. Five of the fatalities were the result of being rolled over by a truck or passenger car causing massive destruction of anatomical structures.

Although one child and two adolescents were injured, the majority of pedestrians with life-threatening trauma were of middle age or elderly (see Table 1). Pedestrians who were killed at the accident site were considerably older with a mean age of 67 years. There were approximately as many male as female victims among pedestrians.

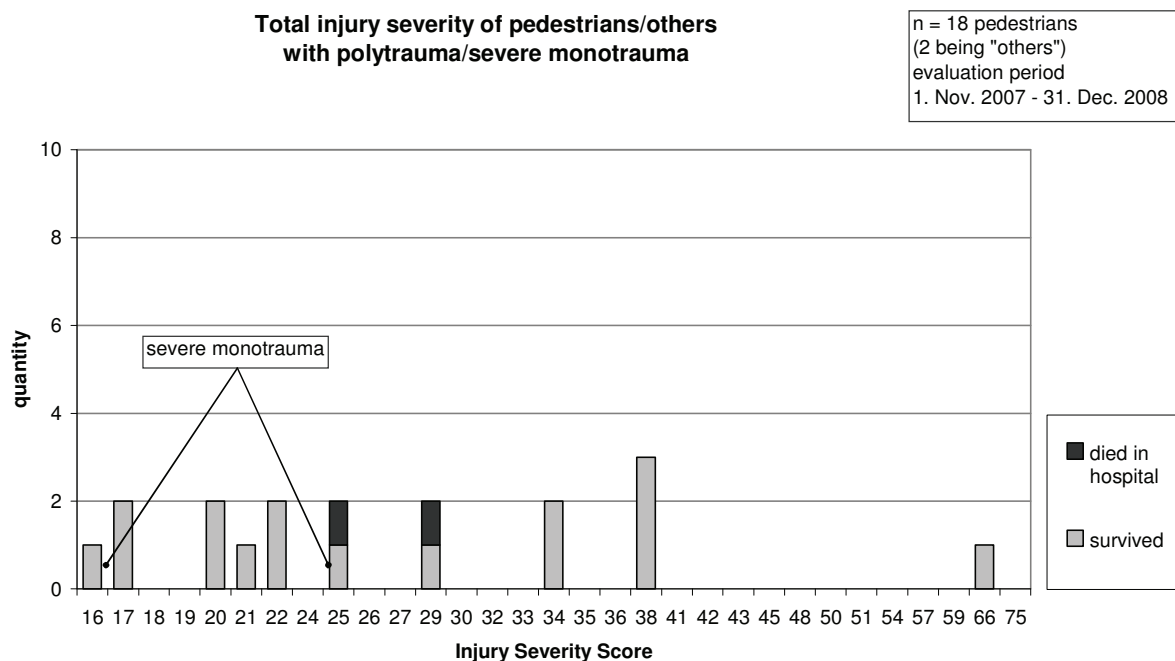


Figure 5. Injury severity of pedestrians treated in hospital, over 14 months

Table 1. Age and gender of most severely and fatally injured pedestrians, over 14 months

pedestrians / others	male (absol. number)	male (relative freq.)	female (absol. number)	female (relative freq.)	age [years] (mean)	age [years] (std. deviat.)	age [years] (median)
polytrauma/ severe monotr.	8	44.4 %	10	55.6 %	42.3	± 22.3	42.5
killed at accident scene	5	50.0 %	5	50.0 %	67.0	± 19.5	70

Cyclists

26 cyclists were admitted to a hospital with life-threatening trauma and five of them deceased later. With three severe mono-traumata located in the head or brain region, cyclists showed the highest rate of injuries in a single body region without any injury in other parts of their body (see Figure 6). Altogether, ten cyclist accidents were single accidents where the rider fell off the bicycle, sometimes at low speed.

In addition, five riders counted as killed at the accident scene (including one elderly person who fell from the bicycle at very low speed, sustained a femur fracture and died later of multi-organ failure), three of them after collisions with a passenger car and one being rolled over by the tractor of a turning semi-trailer.

Of all 31 cyclists in the material, 27 were not wearing a cycle-helmet at the time of the accident. Helmet-use could be confirmed only for one cyclist. The ratio of males and females was approximately 3:2 and the mean age elevated, although not quite as high as among pedestrians (see Table 2).

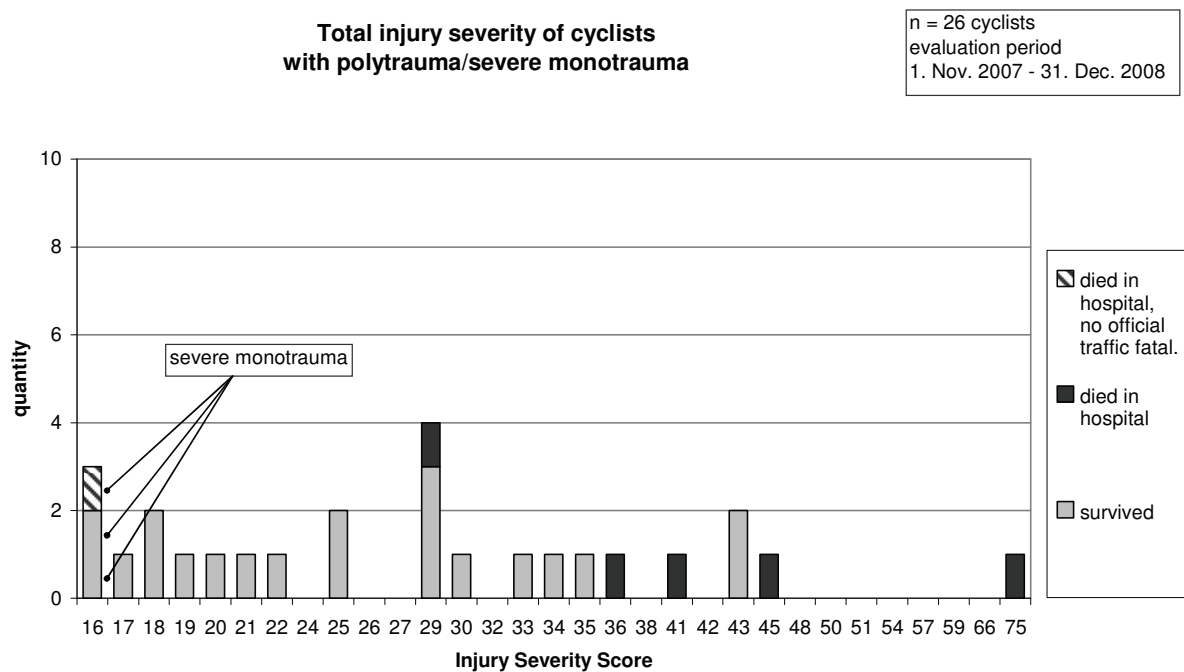


Figure 6. Injury severity of cyclists treated in hospital, over 14 months

Table 2. Age and gender of most severely and fatally injured cyclists, over 14 months

cyclists	male (absol. number)	male (relative freq.)	female (absol. number)	female (relative freq.)	age [years] (mean)	age [years] (std. deviat.)	age [years] (median)
polytrauma/ severe monotr.	15	57,7 %	11	42,3 %	45,2	± 25,5	44
killed at accident scene	3	60,0 %	2	40,0 %	60,0	± 23,9	69

Motor-cyclists

The collected data contains slightly more motor-cyclists than cyclists. Altogether, 35 riders of motor-cycles, including one quad and one trike, i. e., a three-wheeled motor-cycle, sustained a polytrauma (28 cases) or were killed immediately (7 cases). In average, their Injury Severity Score was the highest among all road users with life-threatening injury patterns being treated in hospitals (see Figure 7).

Except for one female co-rider, all motor-cyclists, consisting of 32 drivers and two more co-riders, were males with a mean age of approximately 38 years, including a few teenage and elderly riders (see Table 3). The types of motor-cycles involved in the accidents ranged from bicycles with a small auxiliary engine and mopeds to high-performance motor-cycles. In contrast to cyclists, all but three motor-cyclists were wearing helmets at the time of the accident.

Only one in seven collisions with a very severe or fatal outcome was a single accident that involved exclusively the motor-cycle. In the vast majority of cases, the motor-cycle collided with a car or heavy vehicle, mostly head-on or into the side of the crash opponent.

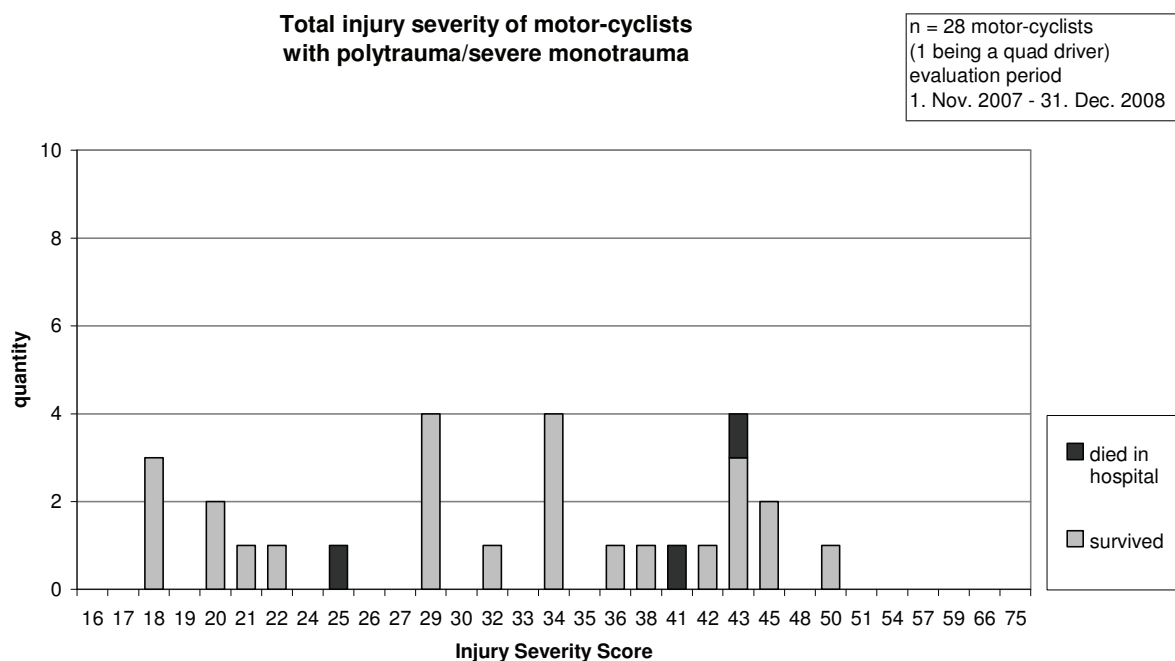


Figure 7. Injury severity of motor-cyclists treated in hospital, over 14 months

Table 3. Age and gender of most severely and fatally injured motor-cyclists, over 14 months

motor-cyclists	male (absol. number)	male (relative freq.)	female (absol. number)	female (relative freq.)	age [years] (mean)	age [years] (std. deviat.)	age [years] (median)
polytrauma/ severe monotr.	27	96,4 %	1	3,6 %	38,5	± 18,5	37
killed at accident scene	7	100 %	-	0 %	38,3	± 14,4	41

Motor-vehicle occupants

77 occupants of cars and commercial vehicles with a polytrauma or severe monotrauma arrived in a trauma center, but eleven of them died later. 54 lost their lives already at the scene. One driver who had supposedly remained uninjured after a medium-severity collision developed medical problems later and died two days later of inner organ injuries. This case is also contained in the latter group.

The recorded Injury Severity Scores cover nearly all possible values between ISS 16 and ISS 43 (see Figure 8). One most severe head injury with an open fracture and brain injury was rated AIS 6, resulting in an ISS 75, consequently. No ISS could be determined for one driver who deceased shortly after reaching the emergency room and before clinical diagnostics were performed.

The comparatively high frequency of values found at ISS 29 and ISS 34 must in part be attributed to numerical effects. For example, an ISS 29 can be obtained both by a combination of AIS 5 plus AIS 2 and by a combination of AIS 4, AIS 2 and AIS 2 injuries whereas an ISS 30 is possible only with the combination of AIS 5, AIS 2 and AIS 1. This effect was described by Stevenson et al. in detail [9]. The group of car occupants with severe trauma contained almost as many females as males (see table 4). However, men were considerably more frequent among the fatalities at the scene. Most severely injured occupants from light vans and goods vehicles were almost exclusively male. Young drivers and passengers in the age between 18 and 25 years represent the largest portion both among patients with life-threatening trauma and fatalities at the accident site which is in accordance with the generally accepted fact that the group of novice drivers displays a higher risk to become involved in severe collisions. On the other hand, also elderly (65 years and above) are prominent in the group of occupants who were killed at the accident site. This phenomenon may reflect the generally higher vulnerability that comes with higher age. Two older drivers were not counted as road traffic fatalities because a stroke and a heart-attack, respectively, had been suspected as the accident cause. However, both sustained also severe head and thorax injuries in the collisions which qualified the cases as relevant for the study. Two children sustained a polytrauma in car crashes and one child of two years, riding in a child-seat on the back-seat, was killed in a catastrophic head-on collision which also claimed the lives of the driver and another rear-seat passenger.

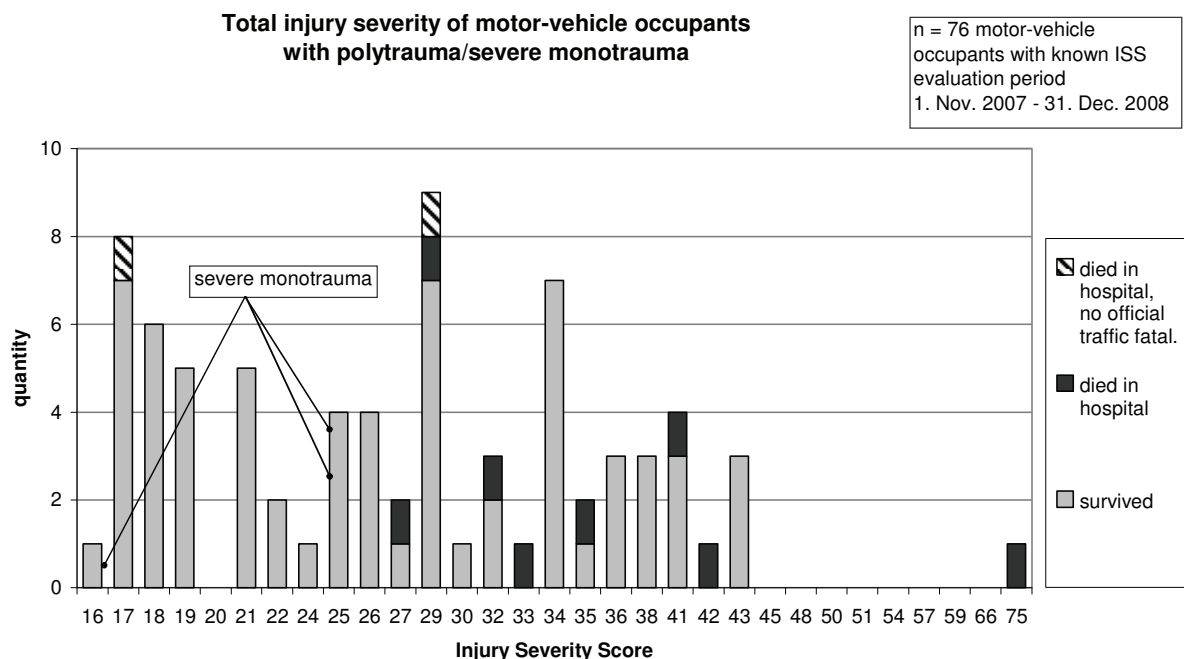


Figure 8. Injury severity of motor-vehicle occupants treated in hospital, over 14 months

Table 4. Age and gender of most severely and fatally injured motor-vehicle occupants, over 14 months

motor-vehicle occupants	male (absol. number)	male (relative freq.)	female (absol. number)	female (relative freq.)	age [years] (mean)	age [years] (std. deviat.)	age [years] (median)
polytrauma/ severe monotr.	43	55,8 %	34	44,2 %	37,6	± 18,4	36
killed at accident scene	39	72,2 %	15	28,8 %	41,5	± 21,4	38

ESTIMATION OF NUMBER OF LIFE-THREATENING TRAUMATA IN GERMANY

With the number of polytrauma and severe monotrauma cases known for the study region in 2008, an estimation of the incidence rate of these life-threatening injury patterns was carried out for Germany. In the first step, the statistical offices of the federal states of Bavaria and Baden-Wuerttemberg where the administrative districts of the study region are situated were requested to provide the numbers of road traffic casualties according to the official categories for 2008. These data allow to determine the ratios of road users with life-threatening injuries as documented for the study and the “seriously injured” or the “fatally injured” according to the national statistics definition. The figures for the latter two categories are certainly available for all accidents reported by the police in Germany. By applying the ratios to the number of “seriously injured” and “fatally injured” on a national basis, two different estimates for the number of patients with life-threatening injuries are obtained. However, one needs to discriminate between survivors of life-threatening trauma who will be allotted to the “seriously injured”, i. e., in-patients for at least 24 hours, and trauma patients who died in hospital within 30 days. Together with road users killed at the scene of the accident, these represent the “fatally injured”.

Table 5. Approaches for extrapolating the number of life-threatening traumata

2008	study region	resulting ratio from study region	Germany	estimate for Germany
“seriously injured” (acc. to official defin.)	1,125		70,644	
“killed” (acc. to official defin.)	80		4,477	
population	1,323,984		82,217,837	
polytraumata / severe monotraumata	131			
of which being “seriously injured” (acc. to official defin.)	112			
of which being “killed” (acc. to official defin.)	16			
of which being “killed” (no official traffic fatal.)	3			
share of survived polytr. / severe monotr. among “seriously inj.” (acc. to official defin.)	112 : 1.125	0.100	70,644 · 0.100	7,066
share of survived polytr. / severe monotr. among “killed” (acc. to official defin.)	112 : 80	1.400	4,477 · 1.400	6,268
share of survived polytr. / severe monotr. related to population	112 : 1,323,984	8.459 per 100,000 inhab.	822.17837 · 8.459	6,955

The number of road users with life-threatening injury patterns is preferably estimated by the ratio of survivors to the number of officially “seriously injured”. With 112 survived polytraumata and severe monotraumata and 1,125 seriously injured for 2008 in the study region a ratio of 10.0 % results (see table 5). When this percentage is employed to the 70,664 seriously injured in Germany for the same period, 7,066 surviving patients can be expected. This approach appears to predict the real number of most severely injured from traffic accidents quite well since an estimation via the population in the study region and in Germany delivers similar figures (6,955 surviving patients).

The alternative approach to determine the ratio of survivors with life-threatening trauma and the number of fatally injured yields a considerably smaller number for entire Germany (6,268 survived polytraumata and severe monotraumata). Since fatal outcomes are less frequent and the determining factors rather random this estimate is considered to be less reliable.

Altogether, 7,000 patients with life-threatening injury patterns after traffic accidents can be regarded as a reasonable estimate for the situation in Germany in 2008 who constitute a 10 % portion of the “seriously injured”. However, one needs to bear in mind that emergency rooms of trauma centers will see approximately 8,150 of these cases, considering the fact of lethality during clinical care.

DISCUSSION

The approach of this study to combine retrospective and prospective methods in order to obtain detailed information about an accident and its consequences cannot replace accident research by on-the-spot investigation. Yet, it can be an alternative to gathering data exclusively in a retrospective manner, particularly about severe accidents and when special types of accident or parameters are of interest. Owing to the fact that information is provided by different project partners, approval from the contributing institutions and responsible authorities in the planning phase is as important as continuous communication with them to ensure a high level of documentation quality throughout the data collection period.

The results of this study are subject to some limitations. Although it could be shown that the chosen region is a good representation of Germany with regards to severe accidents in average, the area is not a perfect model of the entire country. While the share of motor-cyclists among all seriously injured road users in the region is very similar to that in Germany it is considerably lower when considering fatalities. This may be explained in part by the fact that the annual mileage driven by motor-cyclists is more than 25 % lower than the German average [10]. The share of killed car occupants is notably larger in the study region than in Germany, but very similar when measured by the number of seriously injured. With merely one truck driver in the material, the study appears to underestimate the incidence of collisions involving large goods vehicles. A plausible explanation for this phenomenon is the fact that accidents with most severely or fatally injured truck occupants often occur on motorways (“Autobahn” in Germany) as rear-end collisions among heavy vehicles. One of the two motorways running through the region was under construction to a large part during the study period and the speed limit therefore reduced. This may have had a positive effect on severe accidents. Severe casualties of cyclists may be slightly over-represented in the study region whereas pedestrians are possibly slightly under-represented in comparison to the average German situation. A larger share of pedestrians and a smaller share of cyclists among the patients in the DGU Trauma Register confirm this assumption [6].

Finally, it has to be noted that a small amount of most severely injured patients may have escaped the count. However, this percentage is estimated to be lower than 5 % because all documented fatalities from the region could be matched with the official death toll, and police reports of severe accidents did not indicate any immediate life-threatening trauma that had been overlooked in the course of the study. The results of the study suggest that one in ten accident victims who are categorised as “seriously injured” in German national statistics has to be regarded as “most severely injured”, i. e., sustained life-threatening injuries, but survived. According to clinical documentation, approximately one third of the patients were discharged home while the remaining survivors were scheduled for subsequent rehabilitation or were transferred to therapeutic centers or nursing homes. This supports the findings of several studies on the consequences of severe multiple injuries [2, 4].

The German Highway Research Institute BAST published a research work in 1994 which evaluated data from German compulsory health and accident insurers in order to determine the rate of patients who suffered long-term impairment after a traffic accident [11]. The material was not limited to polytrauma patients, but included also patients with other disabling injuries, even if not life-threatening. A rate between 8.5 % and 12.2 % (10.4 % in average) of these victims among the “seriously injured” was calculated which is almost identical to the percentage of life-threatening trauma found in the present study.

Occupants of passenger cars represent the largest share among the most severely injured which is consistent with the frequency of this vehicle type involved in accidents with personal damage in general. However, it was rather unexpected that almost half of the patients admitted to a hospital with life-threatening injuries were female. Further analysis of the data suggests that the higher vulnerability of women in general and a different seating position of small-statured drivers in front of the steering wheel and the instrument panel may play a role. Other trauma studies usually report a considerably higher share of men than women in their case material. The discrepancy may in part be explained by the fact that these studies usually report road traffic victims in general and do not discriminate between types of road users. When all types of road users, including commercial vehicle occupants, motor-cyclists etc., are considered the present study material displays a 2:1 ratio of male to female patients.

Motor-cyclists demonstrate not only the most severe traumata in terms of Injury Severity Score, but their injury patterns often consist of a large number of injuries in different body regions. This is not fully reflected in the ISS because only the most severe injuries for each of the three body regions contribute to the calculated value.

Beside polytraumata, the present study collected also severe monotraumata with an ISS of 16 and over. With only eight cases, their share is comparably small, but a considerable risk for disability or death of the patient remains since all injuries were located in the head/neck-region. Isolated head injuries appear to be relatively prominent in cyclist falls without a preceding collision.

SUMMARY AND CONCLUSIONS

In light of a steady reduction of the number of fatalities and efforts to further improve road traffic safety, most severely injured have come into focus in Germany and other countries. The injury severity categories used in national accident statistics do not account for such victims which is why little information exists about their incidence among all casualties and the circumstances that lead to such severe trauma. A total collection of all life-threatening traumata from road traffic accidents and documentation of their circumstances was carried out over 14 months in a clearly defined study region that represents the German road infrastructure and accident situation well. A 10 % share of life-threatening traumata among seriously injured was determined that translates into at least 7,000 cases in Germany in 2008. Different criteria to describe a most severely injured victim can easily result in very different estimates on a national basis, however. Defining simple, yet meaningful criteria for most severely injured survivors is therefore considered a key factor if national accident statistics should incorporate an additional category for casualties in the future. The definition for a life-threatening injury pattern based on an Injury Severity Score of 16 or above as it was used for this research work is not only compatible with many studies on severe multiple injuries in traumatology, but – to a limited degree – reflects also the risk of long-term impairment after high-speed trauma.

The study material with detailed information on both medical and technical aspects highlighted several injury-causing effects that should be addressed with enhanced passive and active safety systems of modern cars [12]. Furthermore, these data provide indications which characteristics at the accident scene could serve as suitable injury predictors for emergency medical personnel in pre-clinical and early clinical care.

It would be desirable to repeat the study in a different region to broaden the case basis and allow comparison of accidents with very serious outcome as well as the quality of the rescue chain. With the Trauma Register of the German Society for Trauma Surgery (DGU), a database already exists to compare clinical treatment in different trauma centers and the patient outcomes.

ACKNOWLEDGEMENTS

This study was funded by the Loss Prevention Commission of the German motor insurers. The authors would like to thank all supporting organisations and individuals who have either given permission to access data or have actively contributed with information, documentation and expertise. Special appreciation is extended to the Ministries of Interior of Baden-Wuerttemberg and Bavaria, the police headquarters Ulm, Schwaben-Sued/West and Schwaben-Nord and the fire departments of the region, the emergency dispatch centers in Ulm, Krumbach and Augsburg and the staff at the hospitals at the University Hospital and Hospital of the German Armed Forces in Ulm and the Augsburg Hospital.

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