Car Crashes With Polytrauma In Southern Germany

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ABSTRACT

Multiple, life-threatening injuries, often termed polytrauma, do not only demonstrate a high risk of mortality, but also for long-term or persistent disabilities for surviving victims. Road traffic accidents represent the most frequent cause for polytraumata in Germany. However, there are only estimates for the annual incidence rate of these critical injuries and little information exists about the share of different road users among these patients and their respective injury patterns. This is partly due to the fact that – at least in Germany – these most severely injured cannot be identified from national traffic accident statistics.

A multi-center study is being conducted in a large part of southern Germany that attempts to document all polytrauma cases from traffic accidents and the circumstances of the collisions in a defined geographical region over a 14-month period. Patients with an Injury Severity Score ISS > 15 and injuries in at least two body regions are included for evaluation. This paper describes injuries sustained by 34 car and minivan occupants during the first months of the study, the related collision configurations and the vehicle passive safety features that were used or activated, like seat belts and airbags. Most of the occupants were between 18 and 45 years old. More women than men had severe multiple injuries, especially in the range above 35 years of age. Drivers were by far the largest group among the patients and a substantial number of them were unbelted. Many of the involved vehicles were from the small or compact car segment and belonged to older model generations, but most of them featured driver and passenger airbags and sometimes also airbags for side protection. The most severe injuries (AIS 4 and 5) were those to the head and especially to the thorax. Severe spine injuries were few and limited to side impacts or ejection from the vehicle.

INTRODUCTION

High-speed impacts from road traffic accidents are a major cause of polytrauma. Polytraumata have a high mortality risk and are considered a major challenge both for the pre-hospital treatment and the intensive care in the trauma center. Beside its acute danger to the life of the accident victim, there is also a high potential for long-term or persistent disability.

The motivation for this study came from the results of a pilot study that was conducted by the German Highway Research Institute (Bundesanstalt für Straßenwesen BASt) in 2004 and published as a summary in 2005 [1]. BASt tried to determine the incidence rate of “most severely injured” from traffic accidents in Germany and its development over several years. “Most severe injuries” were defined as injuries which cause permanent or long-lasting disabilities. For this purpose, hospital diagnosis statistics, national statistics for the disabled and data from the trauma registry of the German Society for Trauma Surgery (Deutsche Gesellschaft fuer Unfallchirurgie DGU) were analysed. Based on these figures, the authors could not observe a decrease in the number of “most severely injured” over a nine-year period whereas road traffic fatalities have seen a steady decline during these years in Germany. A follow-up study was commissioned to analyse the
trauma registry in more depth and obtain more insight into this phenomenon [2].

An earlier study for BAST had evaluated data from German compulsory health and accident insurers and concluded that most severe, but survived injuries have a share of approximately 10% among the seriously injured in Germany [3]. Like in many other countries, the German national accident statistics define “seriously injured” as traffic accident victims who remain in the hospital for 24 hours or more and survive at least 30 days.

Although impairments may also result from injuries that are not life-threatening, e.g., isolated injuries to the lower extremities, polytrauma have a particularly high potential to cause disabilities for the surviving patient. However, only estimates exist for the incidence rate of polytrauma in Germany. Extrapolated figures from hospital statistics for the total number of new polytrauma cases in Germany range between 32,500 (Haas et al. [4]) and 35,000 (Kuehne et al. [5]) annually, caused by work accidents, falls from great height or other injury mechanisms, including traffic accidents. Liener et al. [6] determined the incidence of severe multiple injuries in one German county and city for the period from 1996 until 2000. The extrapolated rate for Germany yielded 18,700 polytraumatized patients and was considered to underestimate the average rate for Germany.

Beside the lack of knowledge about the number of polytraumata from road traffic accidents in general, their distribution among the different kinds of road users (pedestrians, cyclists, motor-cyclists, passenger car and heavy vehicle occupants) and the circumstances of the incident (e.g., the kind of collision or the seating position in motor vehicles) are largely unknown.

**Objective and methodology of study**

This multi-center, interdisciplinary study was started by the end of 2007 with the objective to document all polytrauma cases caused by traffic accidents in a defined geographical region [7]. The time period for the prospective collection of relevant incidences comprised the months of November and December of 2007 and the complete year 2008, altogether 14 months. Accidents were recruited for the study when they occurred in public space and when at least one of the victims sustained life-threatening multiple injuries, i.e., a polytrauma, or died at the scene of the accident. Data were obtained from trauma centers, the police and district attorneys, from rescue dispatch centers and fire departments in the region.

The most important descriptors of the patients like age, gender etc. and their injuries and pre-hospital and clinical treatment were documented. Furthermore, vehicular parameters (e.g., air bag equipment and seat belt type, vehicle mass) and the characteristics of the collision (e.g., kind of road user, impact direction, collision opponent, depth of occupant compartment deformation) as well as the use of restraints and protective gear (e.g., seat belt, motorcycle helmet) were determined.

Six counties and two larger cities in the southern part of Germany which form one coherent area were chosen as a study region for several reasons. The region features both urban and very rural areas and different types of roads including two major motorways (“Autobahn”) crossing it in the east-west and north-south direction. There are three trauma centers which are suited for the treatment of polytraumatized patients. Other hospitals in the area provide only basic medical care so that the vast majority of accident victims with multiple life-threatening injuries will be transported to one of the three maximum care hospitals. Patient names, adresses, license plate numbers on photos etc. were sanitized before being made available for evaluation so that all personal data remained anonymous to the project coordinator. The amount of patient data and the collection method for this study was reviewed and accepted by the ethics committee at the University of Ulm. Relevant data about injuries, vehicles and their damage as well as general characteristics of the collision were entered into a Microsoft Office Access © database for analysis.

**Representativeness of study region**

The study region comprises eight administration districts in southern Germany, consisting of six counties and two larger independent cities, and covers an area of 5545 km² with approximately 1.32 million inhabitants [8, 9]. In many ways, the conglomerate of counties with a rural character and densely populated cities that form the study territory resembles the situation for entire Germany regarding demographic and infrastructural, but also traffic accident data. Both the population density and the density of the road network outside of built-up areas are very similar to those of Germany in average [7]. The ratios of fatally, seriously and slightly injured per 1000 inhabitants demonstrate good comparability, too. These figures were determined from official road casualty statistics for the respective administration districts and for entire Germany for the years 2005, 2006 and 2007. Comparison of the number of casualties per 1000 inhabitants indicates that the incidence rate of seriously injured was slightly below the national average, not only for 2007, but also for the two previous years (Fig. 1). The rate of fatalities matches that for Germany very well, although it was slightly higher than the national figures in 2005 and
A statistical comparison of accident rates on motorways is not possible due to the small absolute numbers of casualties on this kind of road in the study region. The frequency of killed or seriously injured on motorways within the region tends to underestimate the accident situation on a national basis, however. Nevertheless, the study region can be regarded as a good representative for the German situation when analysing accidents with most severely injured.

Seriously injured per 1000 inhabitants in 2007

<table>
<thead>
<tr>
<th>County/City</th>
<th>Serious Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alb-Donau-Kreis</td>
<td>0.866</td>
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<tr>
<td>City of Ulm</td>
<td>0.946</td>
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<tr>
<td>Aichach-Friedberg</td>
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<tr>
<td>City of Augsburg</td>
<td>0.917</td>
</tr>
<tr>
<td>Neu-Ulm</td>
<td>0.866</td>
</tr>
<tr>
<td>Dillingen/Donau</td>
<td>0.651</td>
</tr>
<tr>
<td>Baden-Wurttemberg Kreis</td>
<td>0.317</td>
</tr>
<tr>
<td>Bavaria total</td>
<td>0.866</td>
</tr>
<tr>
<td>Germany total</td>
<td>0.946</td>
</tr>
</tbody>
</table>

Figure 1. Incidence rate of seriously injured per 1000 inhabitants for counties/cities of study region, federal states of Baden-Wurttemberg and Bavaria and Germany.

Fatalities per 1000 inhabitants in 2007

<table>
<thead>
<tr>
<th>County/City</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Neu-Ulm</td>
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<tr>
<td>Dillingen/Donau</td>
<td>0.073</td>
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<tr>
<td>Baden-Wurttemberg Kreis</td>
<td>0.069</td>
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<tr>
<td>Bavaria total</td>
<td>0.069</td>
</tr>
<tr>
<td>Germany total</td>
<td>0.073</td>
</tr>
</tbody>
</table>

Figure 2. Incidence rate of fatalities per 1000 inhabitants for counties/cities of study region, federal states of Baden-Wurttemberg and Bavaria and Germany.

Rescue and pre-hospital care

Pre-hospital care after traffic accidents is generally provided by ground ambulances. After severe collisions, an emergency physician will be alerted, too, either immediately by the rescue dispatch center or if the ambulance team requests medical assistance. Mostly, the physician will join the scene by car (so-called “rendez-vous” system) or by rescue helicopter. One such helicopter is stationed at one of the maximum care level hospitals in the region and a large portion of the study region lies within its regular operating radius. Other helicopters are located at hospitals in neighboring regions and cover most of the remaining part of the region (Fig. 3). Rescue helicopters will typically be called if the accident location cannot be reached in due time by a ground-based emergency physician or if the accident situation requires several medical professionals. However, air rescue availability is very limited during darkness or under severe weather conditions.

Rescue Helicopter

The general philosophy in the German rescue system for treatment of severely injured is to provide pre-hospital care at the scene to allow a safe transport of the patient to the next suitable hospital. Medication, intubation or thorax drainage will be performed mostly or exclusively by emergency physicians. Nevertheless, a very rapid rescue and transport of the victim may be ordered if the necessary means for diagnosis or treatment are available only in a hospital (e.g., in case of massive internal bleeding). Patients in critical condition or where such a situation may develop will be transported to the trauma center either by ground ambulance or rescue helicopter and accompanied by the physician. Therefore, all cases which were recruited for the present study included the presence of emergency physicians and the admission to an emergency room. The large majority of the polytraumatised victims from road traffic accidents were taken directly to one of the three trauma centers in the region. Only few were transported to other maximum care hospitals, mostly by helicopter and when the collision involved several
severely injured. Cases where a patient was initially taken to a hospital of lower care level and had to be transferred to a maximum care level facility later were very rare in our study. Fire departments in the region are responsible for the technical rescue after traffic accidents. This includes especially the extrication of entrapped vehicle occupants or if the emergency physician demands a patient-oriented rescue, for instance because of suspected spine injuries. Furthermore, fire departments will be called at night time when illumination of the accident scene or landing spots for rescue helicopters is required. In contrast to some other German federal states, fire departments in the region are not directly involved in medical rescue with the exception of a few communities where fire fighters provide so-called first-responder service to bridge the time interval until an ambulance arrives.

**Polytrauma**

Polytrauma describes the presence of multiple injuries or organ systems in several body regions with at least one of them or the combination of several injuries being life-threatening [11]. In addition, most studies require that the resultant Injury Severity Score (ISS) [12] be 16 points or higher to qualify as a polytrauma [13]. Haeusler et al. [14], however, provided examples that various studies have defined a polytrauma slightly differently in the past, especially between the USA and Germany. This pertains mostly to the number of body regions or the minimum Abbreviated Injury Scale (AIS) value accounted for in the ISS calculation. Both the German Society of Traumatologists (DGU) [13] and Tscherne [11] emphasized the difference between a polytrauma and multiple injuries that do not represent a threat to the patient’s vital status. Sometimes, life-threatening monotraumata with an AIS of at least four points are also subsumed under “polytrauma” although this contradicts the intention of describing multiple injuries. Where a polytrauma definition demands the presence of several injured body regions, variations can be found regarding the required lowest AIS to qualify as a relevant injury. While an AIS 1 in a second body region would suffice some studies demand at least an AIS 2 injury to exclude skin abrasions or other minor injuries from the injury pattern. Another potential source for deviations in the ISS values exists in the definition of the body regions themselves. According to the coding rules of AIS-98 [15], the human body is subdivided into the head/neck, face, thorax, abdomen, extremities and external area. The cervical, thoracic and lumbar spine belong to the head/neck, the thorax and the abdomen portion, respectively. Earlier definitions for the six body regions defined the head separately and included the face in the neck region [16]. In certain cases, these differences alone will result in different ISS values for the same injury pattern. For instance, an injury pattern of

- brain injury (AIS 3)
- facial injury (AIS 1)
- cervical spine injury (AIS 2)
- thoracic injury (AIS 2)

will result in:

\[
\text{ISS} = 3^2 (\text{AIS}_{\text{head/neck}} \text{ squared}) + 1^2 (\text{AIS}_{\text{face}} \text{ squared}) + 2^2 (\text{AIS}_{\text{thorax}} \text{ squared}) = 14
\]

when applying the current definition of body regions and will therefore not fulfill the inclusion criterion of ISS > 15 for a polytrauma. The earlier definition of body regions will produce:

\[
\text{ISS} = 3^2 (\text{AIS}_{\text{head}} \text{ squared}) + 2^2 (\text{AIS}_{\text{face/neck}} \text{ squared}) + 2^2 (\text{AIS}_{\text{thorax}} \text{ squared}) = 17
\]

and will consequently classify as a polytrauma.

For different injury patterns, the opposite situation may result. These effects should be borne in mind when comparing study results from populations of trauma patients and polytrauma patients in particular. Our study applies the coding rules of AIS-98 and the most recent definition of body regions. The inclusion criteria for a polytrauma include the documentation of injuries in at least two of these regions and require an ISS greater than 15 points. Severity levels of AIS 1 and greater are considered a relevant injury in our study if the remaining polytrauma criteria are met. Therefore, a single AIS 4 injury, e.g., to the head, that is accompanied by an AIS 1 injury in another region, e.g., overall abrasions in the external area, will be considered a relevant injury pattern. On the other hand, bony injuries like single rib fractures or facial fractures with an AIS 1 will contribute to a polytrauma with this definition whereas they would be ignored otherwise. Where no detailed injury description was available from patient documentation, AIS coding was performed conservatively according to the AIS-98 coding rules.

**STUDY RESULTS**

The following results represent a subset of all polytrauma cases from traffic accident incidences in the study region during the term between November 1, 2007 and December 31, 2008. Since the study design and method of data collection requires several weeks to identify and sufficiently document injuries and the circumstances of the collision only a portion of all polytrauma cases that occurred during the entire study term is currently available for evaluation. The accidents included for this work come primarily from...
the first half of the study period where winter conditions may have played a greater role than during the second half. Furthermore, this subset is restricted to car and van occupants who reached the hospital alive and where a polytrauma was confirmed according to the criteria described above. It needs to be mentioned that another 24 car occupants died at the accident scene during approximately the same period in the study region. Since post-mortem investigations of car occupants are rarely conducted in Germany there is very little information about their injuries, but polytrauma can be suspected in many cases from the documented occupant compartment intrusions. In addition, 19 polytrauma cases of motor-cyclists, cyclists and pedestrians were documented and another seven from these groups of road users died before being transported to a hospital.

**Epidemiology**

34 car and minivan occupants suffered a polytrauma (at least two body regions with documented injuries and an ISS > 15) and were available for further analysis. One driver of a small commercial van was included because the vehicle design was derived from a passenger minivan. A statistical analysis was not carried out at this stage, but will be performed with more cases being available.

Of the 34 vehicle occupants, 15 were males and 19 were females. Except for a 7-year-old rear seat passenger, all polytrauma patients were adults with the majority between 18 and 45 years of age (Fig. 4). While more male occupants were found in the group up to 35 years old, female patients dominate in the age groups above 35 years. 26 drivers, four front seat passengers and four rear seat passengers sustained a polytrauma and arrived at the hospital alive. Six of them, three male and three female patients, died in the trauma center.

**Collision configurations**

Among the accidents in which vehicle occupants sustained a polytrauma, front-to-front collisions with another passenger car or commercial vehicle were the most frequent (12 cases). In three additional collisions, the vehicle impacted a tree head-on and in one case the rear of truck-trailer. In 13 cases the vehicle side was struck either by the front of the crash opponent (6 cases) or in skidding accidents when impacting a tree (7 cases). Four incidents with a polytrauma patient occurred in which the vehicle left the road and rolled. Seven collisions involved multi-impacts, mostly situations in which the vehicle ran off the road and impacted several trees. No polytrauma occurred in accidents where a car was struck in the rear.

Fig. 5 shows the distribution of collision configurations among the relevant cases. The denotation indicates the impacted side of the vehicle with the polytrauma occupant and the affected side of the crash opponent or the roadside object. For multi-impacts, the diagram shows the type of collision which represented the most severe of the impacts.

**Occupant protection**

Beside the impact severity and collision configuration the protection of the occupant with seat belt and airbags is of importance. For 63 % of the front seat passengers with polytrauma belt use could be confirmed, but only one of the four rear seat passengers wore a seat belt. As a result, three drivers and two rear seat passengers were ejected from the vehicle in the accident (Fig. 6).

Most of the vehicles had a driver airbag and a passenger airbag. However, depending on the impact severity and direction, only 14 of the 27 driver airbags and eight of the 23 passenger airbags deployed (Fig. 7). The lower rate of passenger airbag deployments can be explained with some vehicles in
which airbag deployment is suppressed if the front passenger seat is not occupied. No malfunction of the frontal airbags, e. g., airbags that had not deployed although the crash scenario would have demanded it, could be seen in the collective. The crash severity as judged by the vehicle deformation was high enough to require an airbag activation in the vast majority of cases. Only one head-on collision of moderate severity with a polytrauma occurred which remained under the trigger threshold. In another case, a passenger car collided with a small trailer that had detached from an oncoming car. Since the impact occurred only at the level of the A-pillar the front airbags were not activated.

Injury severity and injury pattern

According to the collective of patients recruited for this study, all injured car and minivan occupants had an Injury Severity Score (ISS) higher than 15 (Fig. 8). Modal values were found at ISS 17 and ISS 29. The median was at ISS 26. A score value of 42 was the highest ISS among occupants that arrived alive at the hospital. One driver with multiple severe injuries from a frontal crash died within minutes after admission. Since no diagnostic measures were possible an ISS could not be determined for this patient and he was eliminated from further injury evaluation.

Since the polytrauma definition applied here requires documented injuries in at least two body regions there are no ISS values of 16 present. The calculation rule for ISS entails that certain numerical values also do not exist [17].

The maximum AIS (MAIS) values as well as the second-highest AIS values were determined in order to identify the character of these multiple injuries (Fig. 9). When two body regions featured the MAIS value at the same time the upper region was assigned the MAIS, the lower region the second-highest AIS (e. g., for AIS 3 both for head and thorax, MAIS 3 was assigned to the head and second-highest AIS 3 assigned to the thorax). MAIS 4 were the most frequent, followed by MAIS 3 values. Among the second-highest values, AIS 3 were the most frequent severities. The leading injury severities resulted mostly for the thorax and the head/neck region (Fig. 10). For the second-most severe injuries found
per injury pattern, the thorax clearly dominated in frequency.

Life-threatening head injuries (five AIS 4 and seven AIS 5) were recorded in eight collisions which included three side impacts into a tree, two front impacts also into a tree and two head-on collisions with another car. They included subdural hematoma and diffuse axonal injury. Very severe head injuries were absent in roll-over accidents of the collective. Very severe thoracic injuries were found only on the AIS 4 level. However, this was the body region with the most frequent injuries of this severity (18 times). Ten patients had bilateral lung contusions and six had serial rib fractures (five of them in combination with a pneumothorax or hemopneumothorax). These types of injuries occurred both in lateral and frontal impacts and with and without belt use. Thorax injury severities above AIS 3 were not found in any of the roll-overs.

Abdominal injuries higher than AIS 3 were small in number and pertained only to liver ruptures (3 times). Spine injuries were frequent, but usually did not exceed an AIS 2 value. However, five AIS 3 spine injuries occurred (four of them pertaining to the cervical spine), three of them in lateral impacts into a tree and one in conjunction with a pure roll-over. The only AIS 5 injury to the spine resulted from an unbelted driver who was ejected from her car also in a roll-over and sustained a translation injury at the C3-C4 level with a complete cord syndrome.

Injuries to the face and to the extremities were frequent, but did not exceed AIS 3 values in any of the documented polytrauma cases.

Figure 9. Distribution of highest and second-highest AIS values of polytrauma occupants.

Figure 10. Body regions with highest and second-highest AIS values of polytrauma occupants.

Figure 11. AIS 5 and AIS 4 injuries by body region and collision configuration.
Of the six patients who died in the hospital, five were drivers and one was a rear-seat passenger. One belted driver was killed when her compact car skidded on the snow-covered road and hit a tree with the left door (ISS 29). The side airbag could not unfold completely from the seat back and the window airbag was not triggered. In another case, the unbelted driver died after his large-size car had side-swept one tree and then struck another tree head-on (ISS 33). The driver sustained three AIS 5-rated brain injuries while the injuries in the other body regions did not exceed an AIS 2-level.

Two fatalities each occurred in collisions where the drivers of the oncoming cars had lost control and collided head-on with the patient’s vehicles. In both cases, the driver airbag was activated, but their cars received severe intrusions into the occupant compartment and the drivers’ head, thorax, abdomen and extremity regions were injured. The remaining fatalities occurred on street crossings in urban areas, each. One was an 81-year old driver whose small car was struck in the driver side under a 90° angle by a truck and 51-year old rear-seat passenger of a van who was ejected from the vehicle when it was hit by passenger car. Both received severe head and thorax injuries (ISS 30 and ISS 42, respectively).

**Rescue system**

Information on the rescue times and the dispatched rescue vehicles was available for most of the relevant accidents. A simple overview of the times between the incoming emergency call at the dispatch center and the arrival at the hospital demonstrates that in many cases the theoretical goal of a maximum of one hour between the accident and treatment in a suitable hospital could not be achieved. It needs to be remarked here that the German rescue system with qualified medical staff already at the accident site allows to screen the patient for potential injuries and to take measures to stabilize respiration and circulation. In a number of accidents the occupant had to be extricated from the vehicle by the fire department. These actions reached from simple opening or removal of jammed vehicle doors to removing the car’s roof and applying hydraulic rescue cylinders to free entrapped occupants. The overall rescue times appear not to be substantially prolonged by these measures. Interviews with the local fire departments showed that in the majority of cases the technical rescue could be carried out without any problems. Since the overall duration of the rescue chain is influenced by various parameters, like weather and light conditions, accessibility of the accident location and pre-hospital measures, no conclusions can be drawn directly. A closer analysis of the different phases of the rescue chain and their time should therefore be conducted.

**DISCUSSION AND CONCLUSIONS**

The results of the analysis of most severe multiple injuries sustained by vehicle occupants confirm many findings from earlier research. Otte et al. [18] compared polytrauma injury patterns from traffic accidents in the mid-seventies with those from the late nineties. They reported that in contrast to the earlier collective with severe injuries in almost all body regions, the later study group showed life-threatening injuries primarily in the head and thorax.

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**Figure 12. Time from emergency call to hospital admission and technical rescue measures.**
region. Impacts into narrow objects like trees were considered the major cause for these types of injuries. Bakaba et al. [19] analysed the German national road accident statistics and found that more than 1,000 fatalities occurred in impacts into trees in 2007. 85% of these accidents happened on country roads. Our results show a stronger dominance of head-on collisions between motor vehicles among the 34 polytraumatised occupants concerning the number of accidents. Nevertheless, impacts into trees, both involving the front and the side of the car, produced nearly the same amount of AIS 5 and AIS 4 injuries like collisions with other motor vehicles (Fig. 11). Two of the six fatalities among the 34 patients were the result of tree impacts. One contributing factor is that the impact energy is dissipated almost entirely on the side of the car and over a rather small portion of the vehicle structure when a tree is struck. Where polytraumatised occupants were involved in collisions with other cars, the occupant compartment showed severe intrusions and extrication of the patient was required in most cases. Despite the presence and activation of frontal airbags the steering wheels as well as the lower instrument panels were significantly deformed in several of the frontal collisions. This indicates that these cars where subjected to substantially higher impact severities than what they were designed for.

The collective of collisions involving polytrauma includes a large portion of accidents which were caused when the driver lost control of his vehicle on a slippery road surface. In consequence, the car either moved to the opposite side of the road and collided with oncoming traffic or ran off the road where it struck a roadside object or had a roll-over. There may be a bias in our material due to the fact that most of the accidents came from the winter period of the study term.

A considerable share among the occupants with a polytrauma were unbelted (nine confirmed unbelted of 34) while the belt use rate for Germany is 95% in average for car occupants according to the surveys of the German Highway Research Institute [20]. This supposed contradiction may be explained in part by the fact that unbelted occupants generally have a higher risk of being severely injured in a crash. Thus, our collective of polytrauma patients may particularly filter out the unbelted. In addition, other studies found that drivers who do not use their seat belt also tend to display more risk-taking in their driving behaviour [21].

Interestingly, more women than men can be found in our population of polytrauma patients. This appears to be in contrast to some studies on polytrauma that reported a clearly larger number of males than females in their material [22]. There could be several reasons for this phenomenon: first, many studies on polytrauma included patients irrespective of the injury mechanisms. Since these studies include not only traffic accidents, but also mechanisms like falls from great height or workplace accidents, men may represent such a large share among these groups that this affects also the average ratio of male patients in the entire population. Furthermore, polytrauma patients from traffic accidents comprise also pedestrians, cyclists and motor-cyclists whereas our cases are based exclusively on vehicle occupants. Especially the group of motor-cyclists shows a vast share of male users and accident victims as well. With the future inclusion of other road users in addition to vehicle occupants from our study region an answer can be expected. If further evaluation confirms that female car occupants are more prone to sustain severe multiple injuries investigations either into the gender-specific causes of these crashes or into the tailoring of safety systems for women should be intensified.

Modern car structures and restraint systems with airbags and advanced belt systems, including belt tensioners and force limiters in some of the vehicles, have presumably prevented or reduced head injuries in frontal impacts among the polytrauma occupants in our study. Thus, thorax injuries have gained in importance. They are dominated in our material by lung contusions; in frontal impacts often in absence of any rib fractures, in side impacts also in conjunction with rib fractures or hemo- or pneumothorax.

While there is indication that the deployed window airbags contributed much to the prevention of head injuries in some of the side impacts of our study, thoracic injuries are present also with thorax side airbags. Several of the severe lateral impacts into a tree were preceded by other, mostly lighter impacts. It is not possible to tell from the documentation when the side airbags were triggered, but it can be assumed that some deployed during the first contacts before the most severe impact occurred. While window airbags are usually designed to retain their bag pressure for some seconds thorax side airbags, like frontal airbags, will deflate almost instantly. It should therefore be investigated in the future whether pressure retention would be beneficial also for thorax side airbags in multi-collisions and whether this would present a disadvantage for the occupant in single impacts.

In several accidents with a lateral tree impact the car was slightly tilted about the longitudinal axis when the contact with the object occurred. Hence, the deformation was larger in the roof portion than on window sill level. In some of these cases the window airbags were not activated although they probably would have had a protective effect. If it can be verified that this is a common impact scenario for side crashes it be should be accounted for in window airbag trigger algorithms.
Among the five fatalities with known ISS, there were three that exhibited several severe head injuries at the same time. In the maximum, one driver sustained three AIS 5 and two AIS 3 injuries to the brain alone. Because the ISS calculation rule accounts only for the most severe of the injuries in one body region the ISS value will rather underestimate the mortality risk in such cases.

Currently, our work incorporates a rather small number of polytrauma cases from the study region. With documentation of the remaining polytrauma patients and the corresponding circumstances of the accidents becoming available the database will be strengthened to allow statistical evaluation in more depth.

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