Influence of new car body design on emergency rescue

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Abstract
The share of high-tensile steel in car bodies has increased over the last years. While occupant safety has generally benefited from this measure, there is a potential risk that, as a result, rescue time may increase considerably.

In more than 60% of all car occupant fatalities a technical rescue has been necessary. These are in particular those cases where occupants die immediately at the accident scene. Therefore, in these cases "rescue time" is a very sensitive parameter. In addition to the general analysis of the need of technical rescue and the actual rescue time depending on model years, the injury pattern of occupants requiring technical rescue will be analysed to provide advice for rescue teams. Furthermore, a detailed analysis of rescue measures for the most popular car models depending on the safety cell design is given.

INTRODUCTION

Self protection of the car occupants is a key objective for the development of recent cars. In order to achieve this goal the cars are equipped with sophisticated restraint systems. Furthermore, the structure is designed in a way that compartment intrusion is rarely seen in modern cars. These measures in combination with improvements in the infrastructure and medical treatment have resulted in a considerably decrease of the numbers of killed and severely injured car occupants over the last 15 years although the number of registered cars increased and the total number of accidents stayed almost constant, see **Figure 1**.

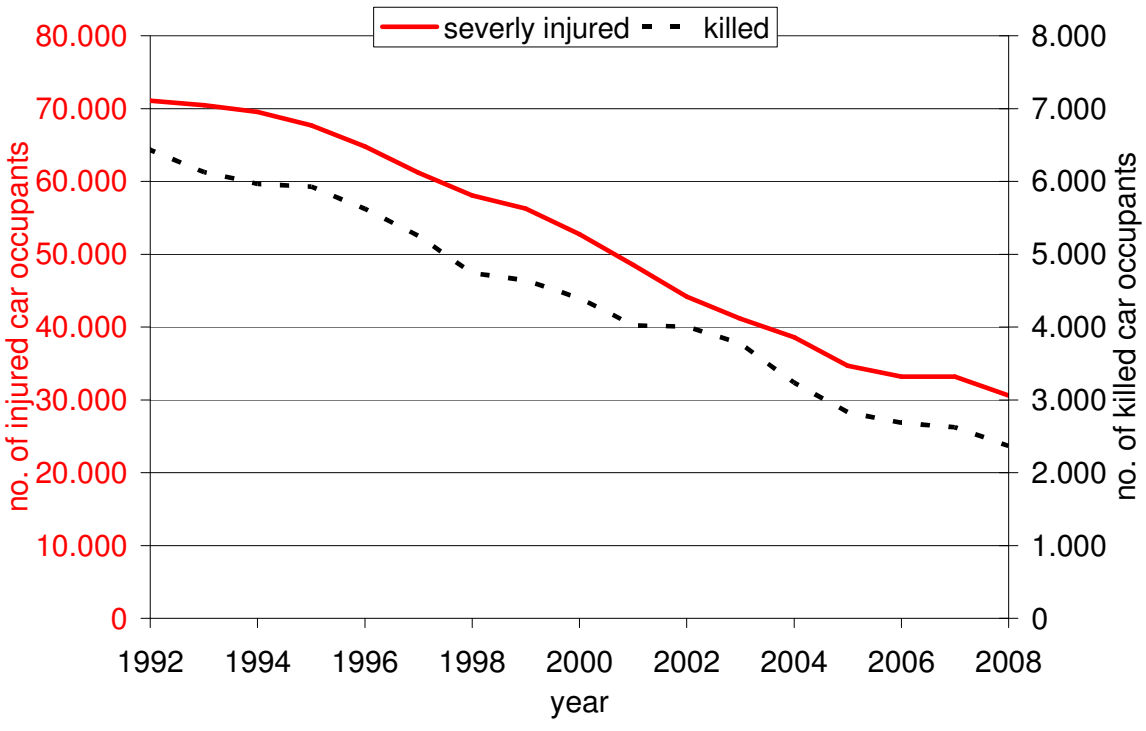

Figure 1. Development of numbers of killed and severely injured car occupants in Germany [1]

Parallel to the technical improvements of cars, the methods, tools and information regarding the rescue of car occupants, too, have been developed further. For the rescue of accident victims two different systems are used world wide. The *scoop and run* system (e.g., used in the US) aims to take the victim to the hospital as fast as possible, while the *stay and play* approach (e.g., used in Germany) aims at stabilisation of the patient at the scene by medical doctors before transport to the hospital. If necessary the medical rescue is accompanied by technical rescue measures e.g. in order to extricate trapped occupants.

With regard to the technical rescue two important factors determine the approach taken. On the one hand, there is the concept known as the "Golden Hour of Shock". The study of Cowley [2] shows that the fatality risk for patients with internal bleedings increases significantly with time before arrival in the shock room. Cowley postulated that there is a golden hour between life and death; patients who are critically injured have less than 60 minutes to survive. That does not mean, of course, that they will necessarily die after 60 minutes but that the first hour after the incidence determines the outcome. Consequently, the Golden-Hour-of-Shock concept motivates a quick technical rescue in order to allow an early intensive medical treatment. On the other hand, there is a potential risk that victims sustained a spinal cord injury during the accident, which could be worsen by rough handling. According to an Australian study [**3**], 28% of spinal cord injuries caused by accidents between 1998 and 1999 were observed in motor vehicle occupants with a majority sustaining spinal cord injuries of the cervical spine. When looking at all victims, a large number of cervical spinal cord injuries are incomplete injuries, **Figure 2**. While there is no risk of worsening complete spinal cord injuries, rescue teams avoid changing an incomplete spinal cord injury into a complete one during rescue actions.

In order to address this risk a careful rescue procedure without relative movement of the spine is envisaged. While in the past fire fighters found a reasonable compromise between quick and careful with regard to rescue operations where old cars were involved, they fear that new car designs could lead to increased rescue time and thus jeopardise the current compromise. Generally new car design in the context of this study started with the introduction of the current ECE R94 (frontal impact test procedure); that means that most of the cars with first registration in the year 2000 or later are included in the "new car" category. Old cars are those which do not comply with ECE R94.

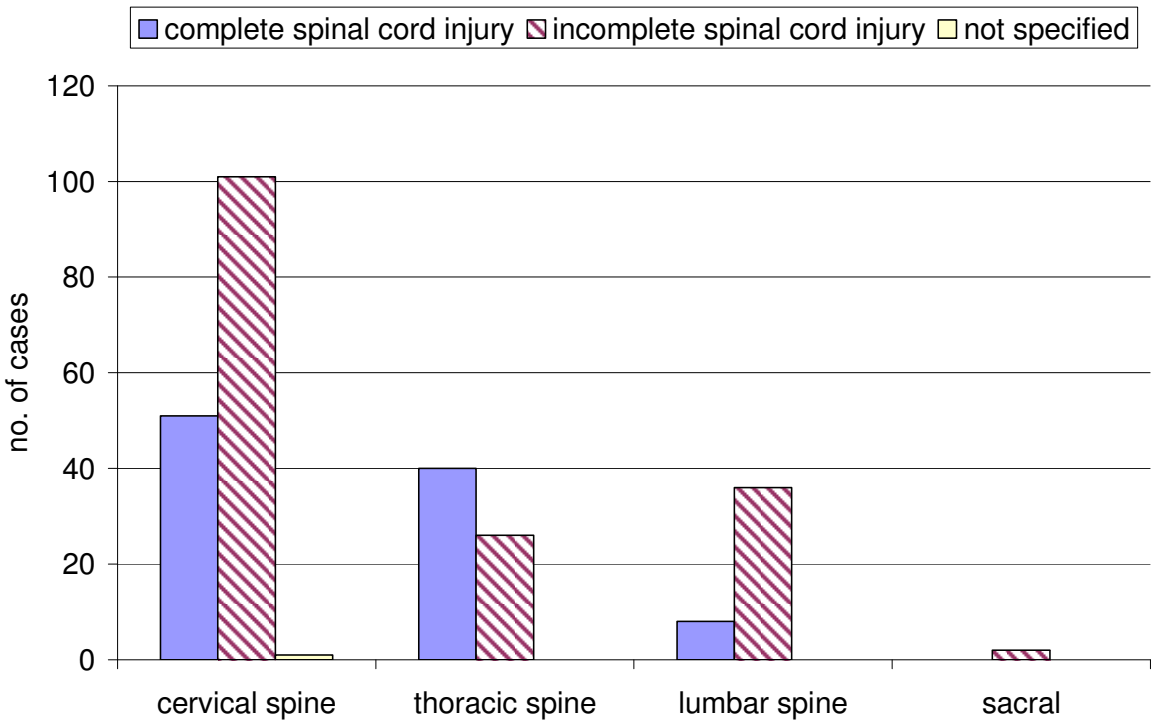

Figure 2. Extend of spinal cord injuries observed in Australian accidents 1998 - 1999 [3]

This paper aims to start a discussion about the needs of victims involved in road accidents with recent cars as compared with older car models in order to adapt the rescue procedures.

TECHNICAL RESCUE MEASURES

The careful rescue approach requires a large opening of the car (e.g., removal of the complete roof or side). The large opening is necessary to prepare the crash victim for the immobilised transport to the rescue van with the scoop stretcher.

For opening the complete roof the surrounding glazing needs to be removed and the A and B-pillar or B and C-pillar needs to be cut at both side of the car in order to fold the roof to the rear or to the front respectively.

Especially the pillar design has changed over the years. A modern pillar consists of more material layers than the old ones. In addition, the used materials are more challenging for the rescue tools. The rescue tool manufacturers address the new design by increasing the power and improving the cutting behaviour of their tools.

Normally, technical rescue measures are necessary because the victim is trapped in the car, e.g. because their feet or legs got stuck between the pedals and the floor or between the dash board and the floor.

RESCUE TIME

Fire fighters often fear that the new car design may require considerably more time for rescue measures than was the case with older cars. In addition to the specific challenges posed by new cars, fire fighters tend to be less experienced because extrication is becoming less frequent with modern cars due to active safety measures and the high strength design. In this chapter, all GIDAS frontal impact data of the years 1999 to 2008 regarding cars with first registration between 1986 and 2008 are analysed in order to assess the relative proportion of technical rescue measures amongst all frontal accidents, as well as to analyse the rescue time needed.

There is a clear trend towards a reduced need for technical rescue measures in frontal impact accidents with newer cars as compared with older ones. Due to the low number of accidents with very new cars it appears more reliable to group different model years and to analyse each group separately. After grouping the model years into three groups the number of cases is sufficiently large to allow for a reliable analysis of the data. For cars with first registration between 1986 and 1993 technical rescue measures were necessary in approx. 5% of the cases, while for the group 2000 - 2008 only for 2.5% of all frontal impact accidents technical rescue measures were necessary, see **Figure 3**.

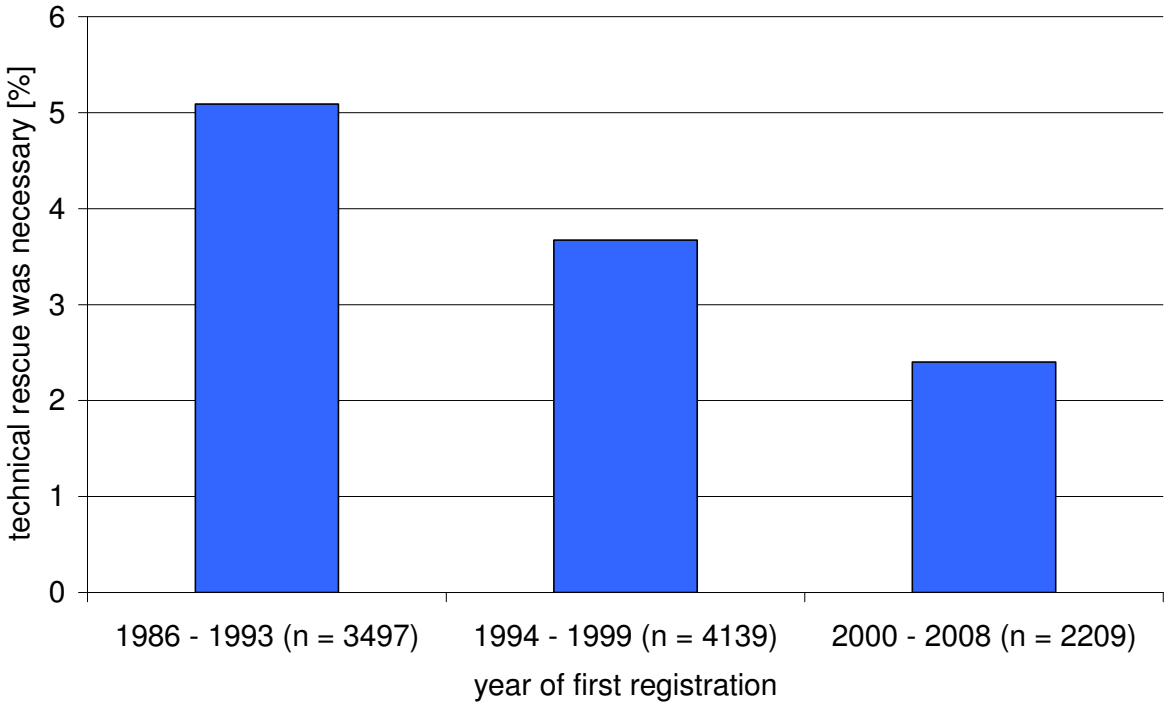

Figure 3. Share of accidents with technical rescue amongst all frontal impact accidents

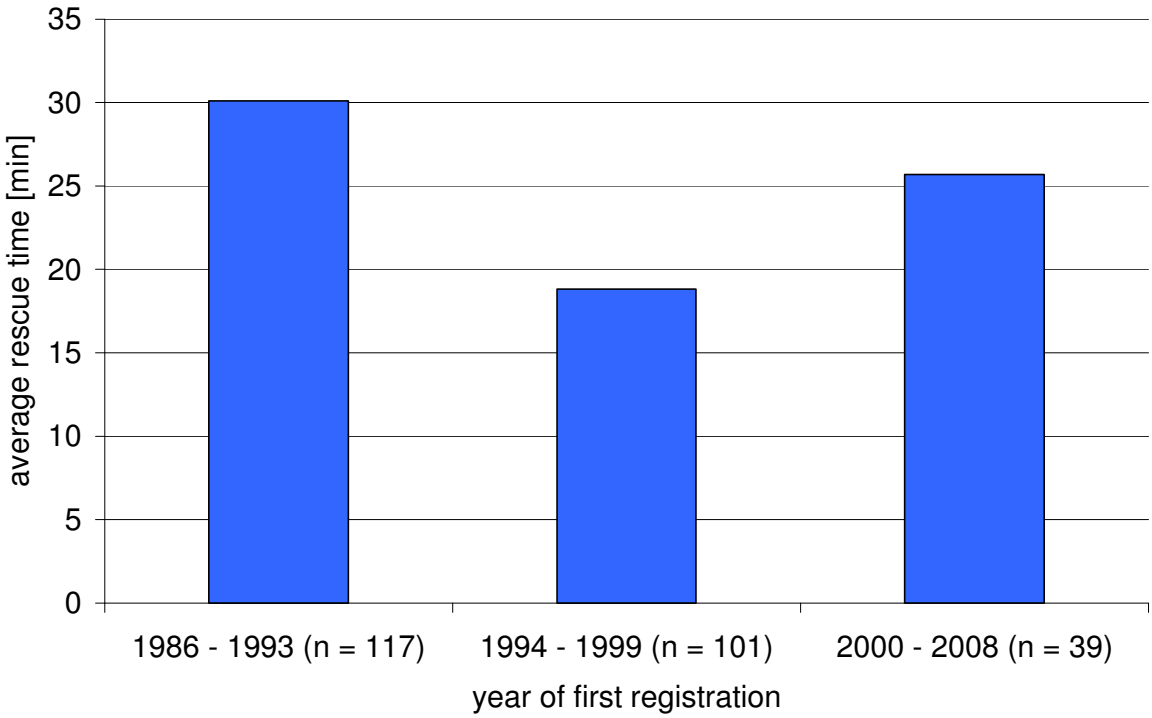

Figure 4. Share of accidents with technical rescue amongst all frontal impact accidents

Information regarding the necessary rescue time was not available in all cases. Therefore, the reliability of the data is smaller compared to the share of accidents with technical rescue measures. In addition, it is important to note that the rescue time does not depend solely on technical issues. The technical rescue operation is often parallel to the medical treatment in order to stabilise the patient. However, based on the available data, there is no evidence that rescue time is increasing with new cars.

CAREFUL VERSUS QUICK EXTRICATION

As already set out in the introduction, there is a trade-off between careful rescue in order not to further mechanically damage the spine (especially the spinal cord) and the quick rescue in order to start intensive medical treatment in hospital as soon as possible. In this chapter, the needs of patients with respect to the evacuation process are discussed and analysed. In the context of this paper careful rescue means the process of introducing a large opening for rescuing with the scoop stretcher while a smaller opening would be sufficient for the quick rescue without scoop stretcher.

Hypothesis

Based on a theoretical analysis of safety measures in cars, a hypothesis concerning rescue needs of accident victims in new cars will be developed. This hypothesis will then be validated or disproved based on the GIDAS data and literature.

The new car design with high-tensile materials will lead to higher cabin acceleration. In addition, the cabin will stay intact more often than in older cars. However, if damage to the cabin requires technical rescue, the accident severity will be much higher.

The higher acceleration pulse in new cars as compared with older ones more often leads to acceleration induced injuries compared to blunt trauma or penetration injuries.

The introduction of airbags results in a more balanced restraining of the torso and head, resulting in lower neck loads.

The introduction of pretensioners, seat ramps, knee bags, etc. reduces the risk of submarining and therefore the risk of lumbar spine injuries and injuries of the lower abdominal organs.

In general, it is expected that time critical internal bleeding injuries will become more relevant and spine injuries with a risk for spinal cord injuries will become less important. Therefore, rescue time should become the leading factor in technical rescue measures. However, careful rescue should not be neglected completely.

Data analysis

In order to check the validity of the hypothesis, GIDAS accident data of the years 1999 to 2009 of car occupants, who received technical rescue, were analysed. The data set was split into the category initial registration between 2001 and 2009 (classified as new cars for this study) and initial registration between 1995 and 2000 (classified as old cars for this study). Data of occupants of older cars were not included.

To analyse the needs of the victims all individual injuries were analysed. The main objective of this study was to define whether or not any injury of each victim required a quick rescue or a careful rescue. For this purpose the following injuries were considered as time critical because they are often connected with a haemorrhagic shock:

- internal organs: ruptures, laceration, haematoma
- major blood vessels: rupture, laceration
- pelvis: pelvic bone fracture
- traumatic brain injuries with structural lesion

The following injuries were considered to be critical with respect to spinal movement and following spinal cord injuries:

- any fracture or partial fracture of vertebral column
- severe damage of spinal ligaments
- any injury of the spinal cord

The chosen classification has its limitations as not all fracture injuries of the vertebrae are critical with respect to spinal cord injuries, and risk factors, e.g. narrow spinal canal and osteoporosis, have not been considered. In addition, it is possible to treat a number of shock victims with internal bleeding at the scene. However, given the aim of this paper, which is to start the discussion about appropriate rescue strategies for occupants of modern cars, this classification appears to be sufficient.

In total, 124 occupants were included in the new car category and 171 occupants in the old car category.

Approx. half of the victims of new cars do not suffer from any time critical injury or any spinal injury. The proportion of patients with internal bleeding is approx. 30%, while approx 10% of the victims have injuries that could be critical with respect to paraplegia. For just under 10% of the sample both injury types (time critical and spinal injuries) for each victim were recorded, see **Figure 5**.

Only minor deviations are visible between the different impact types for trapped occupants in new cars. For lateral impact conditions the risk for spinal injuries increases. However, it is still below the risk for internal bleedings. In rear impact accidents no case was reported with injuries that indicate a risk for spinal cord injuries. However, the number of cases is very small.

Malczyk [**4**] analysed accident data of car crashes in a study region with 1,3 Million inhabitants in southern Germany. The aim of this study was to include all accident victims with poly trauma between November 2007 and December 2008. In most of the cases no spinal cord injury was observed. However, there is a relatively high risk for cervical spine injuries with involvement of the spinal cord for roll-over accidents In comparison to that, 61% of the occupants sustained traumatic brain injuries, 58% sustained lung injuries, 12% liver injuries and 25% spleen injuries [**4**]. These findings also support the hypothesis that quick evacuation is of higher priority than careful extrication.

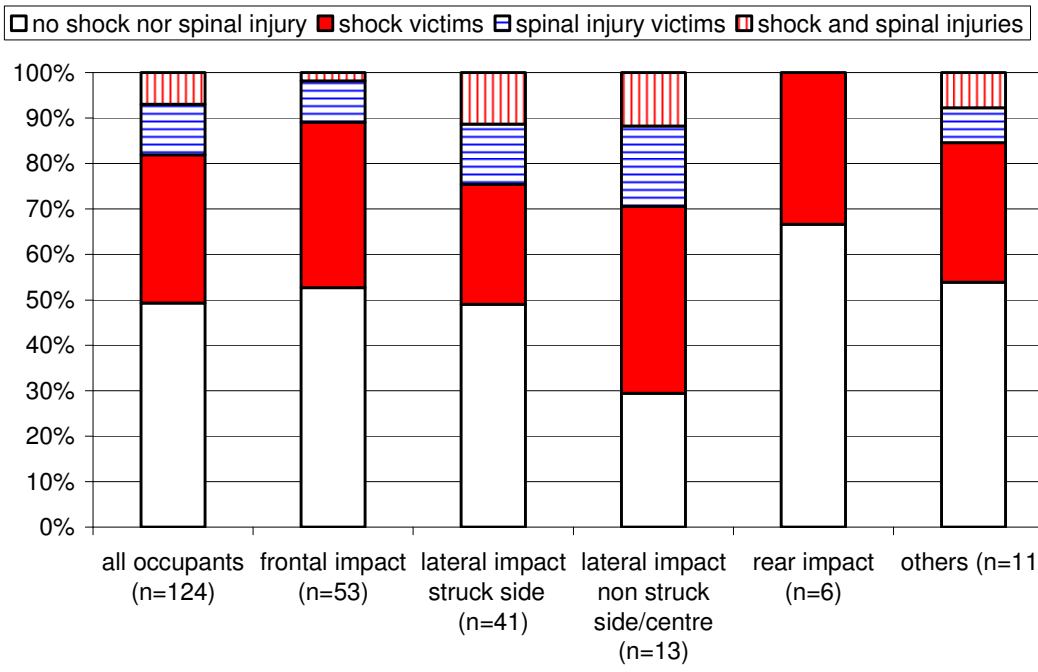

Figure 5. Injury categories for occupants who needed technical rescue in new cars

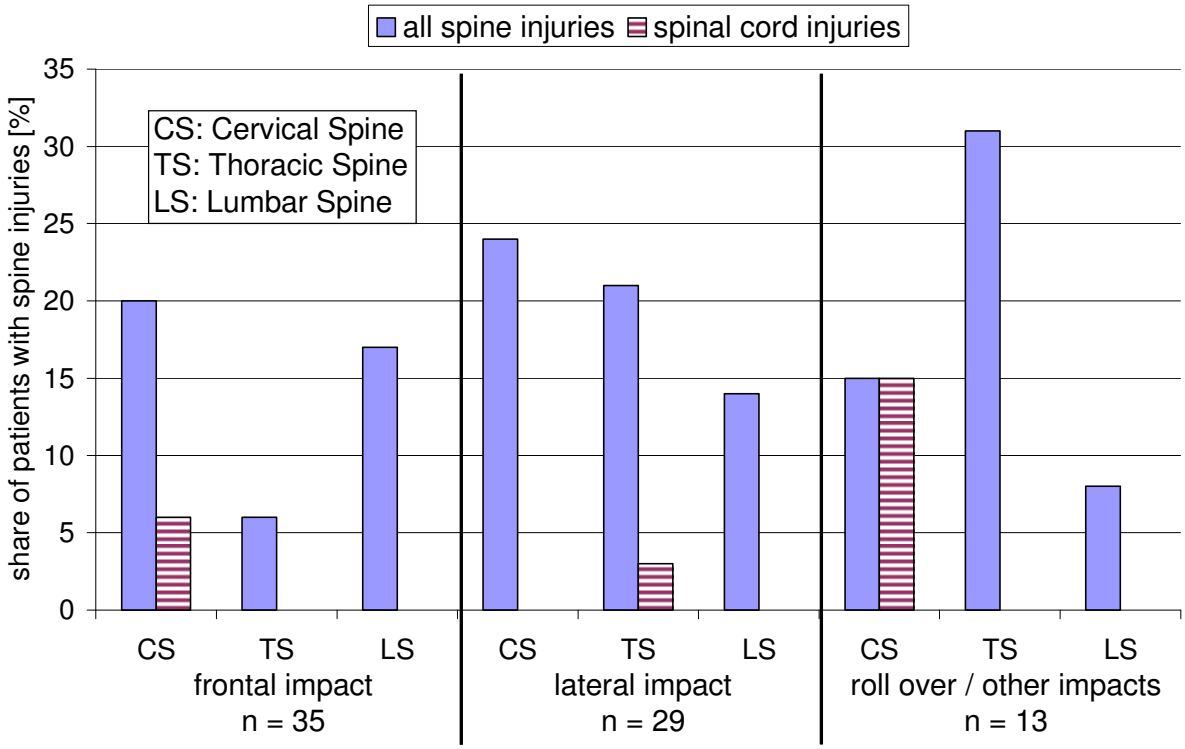

Figure 6: Spine injuries of 77 severely injured car occupants [4]

However, Malczyk was looking for poly-trauma patients or accident victims with highly severe single injuries only. These patients are thought to benefit more than others from quick evacuation.

On the whole, the analysis of the GIDAS data (new cars) indicates that trapped occupants in new cars would benefit more often from a quick rescue than from a careful one.

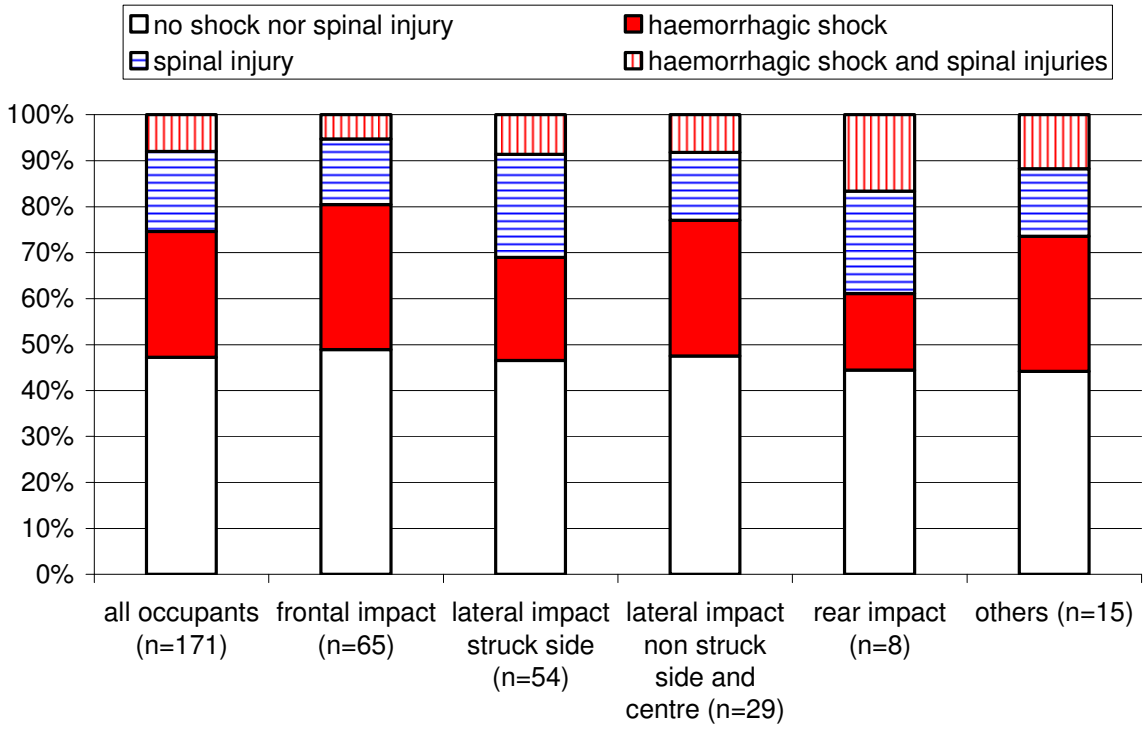

Figure 7. Injury categories for occupants who needed technical rescue in old cars

For a small number of cases of the data described above the rescue time was recorded. The rescue time was counted from the moment the accident happened until the moment the victim was out of the accident situation. The average of this rescue time was 30 min independent of the risk resulting from the actual injuries.

The comparison with older cars (initial registration between 1995 and 2000) shows minor differences, see Figure 7. Careful rescue measures are also less often required with older cars. However, the difference is less clear.

The data analysis indicates that the hypothesis that quick evacuation in recent cars is more important than careful extrication is correct. However, because of the discussed limitations with respect to the fuzzy analysis method and the small number of analysed cases further research is needed to completely validate the hypothesis.

CONCLUSIONS

The analysed data indicate that there are differences for different types of accidents (e.g., the risk for spinal cord injuries is higher in lateral impacts compared to frontal ones). In addition, it is anticipated that the belt use also has a significant influence on the type of injuries and therefore the appropriate rescue method. Individual decisions based on the findings at the scene are therefore necessary. Although, in principle, modern diagnostics as employed at the accident scene already allow to assess whether or not life threatening injuries can be expected, the analysis of the rescue time indicates that these techniques have their limits as no difference in the rescue time was observed for the group with high risk for spinal cord injuries or high risk for internal bleeding.

Risk analysis based on the accident scenario requires dedicated guidelines how to “read” accidents. To be able to develop these guidelines it is necessary to further analyse accidents involving technical rescue measures in order to obtain a better understanding of the different scenarios. To organise a data exchange between hospitals, medical rescue teams, and technical rescue teams in order to evaluate rescue methods based on the outcome appears to be a good step forward in achieving this goal.

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