CERVICAL SPINE DISTORTION INJURIES IN VARIOUS CAR COLLISION DIRECTIONS AND INJURY INCIDENCE OF DIFFERENT CAR TYPES IN REAR-END COLLISIONS

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ABSTRACT

This study focuses on typical characteristics of car accidents that may influence the extent of Cervical Spine Disorder (CSD) injuries and the subsequent recovery process. A statistical analysis of long-term CSD injuries in rear-end collisions was also performed, placing particular emphasis on the car models involved.

754 accidents were investigated retrospectively by analyzing insurance records (HUK – Coburg) in terms of the Quebec Task Force Injury Classification (QTF). Accidents were classified according to collision direction: frontal, rear-end and lateral. Statistical analysis of rear-end collisions by car type was performed using three categories: not injured, CSD injury, long-term (> 6 weeks) CSD injury.

The range of delta v for frontal impacts where passengers sustained a CSD injury was higher than that for other types of collisions (24.9 km/h, compared with 16.5 km/h for rear-end impacts, 15.2 km/h for lateral impacts). Women showed a higher risk than men of suffering from a CSD injury. In frontal impacts the extent of general injury was higher than in rear-end impacts. 20% of patients received treatment lasting 1-2 weeks and 30% received treatment lasting 2-6 weeks. The duration of absence from work varied according to the severity of the injury (QTF I: 11 days versus QTF II: 16 days and QTF III: 23 days).

Differences were also identified in the incidence of long-term injuries between various car types in the same weight class and with the same driver.

According to our results, females represent the highest CSD risk group in all collision types. Thus, protection measures should focus on this group in particular. Frontal test conditions should be in a delta v range of 23–30 km/h. Analysis of the results on the basis of different car models clearly demonstrated a discrepancy in the protection levels afforded by the different models.

KEYWORDS

- ACCIDENT ANALYSIS
- WHIPLASH
- REAR-END, FRONTAL AND SIDE IMPACTS
- REAR-END CAR CRASHWORTHINESS

CERVICAL SPINE DISTORTION INJURIES play a major role in car-to-car collisions worldwide. The high rate of CSD injuries would appear to represent not only an economic burden but also a medical challenge. A particular characteristic of so-called “whiplash” injuries is that they can occur in car accidents at low velocity (Richter, 1999). During such accidents, seated persons are prone to hyperextension of the neck, particularly at the level of the C6/C7 cervical vertebrae (Kaneoka, 1999).

Research into vehicle safety is making progress, but nevertheless the number of incidences of cervical spine injuries in motor vehicle accidents is not falling. The motor vehicle industry tends towards

the production of stiffer car bodies which appear to protect the car's outer shell rather than the passengers themselves in the event of a collision.

MATERIAL AND METHODS

MATERIAL

The data was taken from insurance records (HUK – Coburg: 10% market share of all German car insurers) including police records, technical expert opinions, medical records and post-mortem examination papers. The data was evaluated by engineers and physicians at the Institute for Vehicle Safety.

Only accidents that occurred in the year 2000 were selected. The lower limit of total damage was set at 1533.88 €. Multiple collisions were excluded. The apparent age of the claimant's car could not exceed 10 years. At least one person displaying a CSD injury should be present in the claimant's car.

Insurance records were selected manually, and cases involving rollover, older vehicles, trucks and vans were eliminated.

According to medical records, 660 accidents involved drivers who sustained CSD injuries, a further 186 caused injury to front seat passengers. A total of 754 accidents (44% frontal impacts, 9% lateral right, 14% lateral left and 33% rear-end impacts, see Table 1) were investigated, as a result of which 872 occupants (drivers, front seat passengers and rear seat passengers) were observed to have sustained CSD injuries .

Main Impact	No. Total	%
Frontal	332	44,0
Right	69	9,2
Left	107	14,2
Rear-end	246	32,6
Total	754	100,0

Table 1 – Impact Directions

To indicate the severity of the crash, the "change of velocity" (delta v) parameter was chosen. This value is produced by a computer calculation program (PC Crash, TU Graz). Hence, each value for delta v was the product of a reconstruction process. Due to budgetary and staffing restrictions, only 150 out of 754 cases were reconstructed (Figure 1).

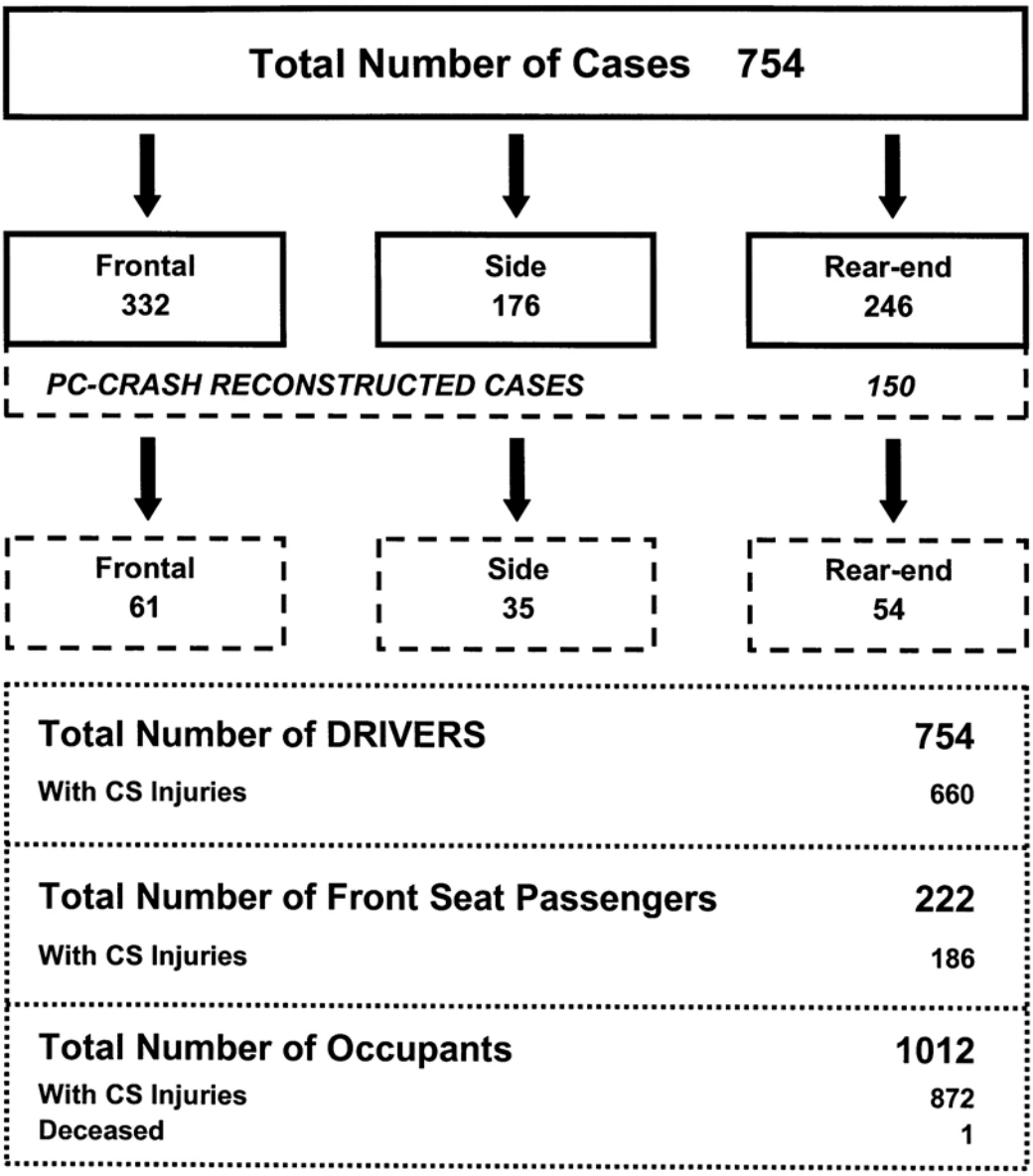

Fig. 1 – Structure of Investigated Data

METHODS

Descriptive evaluation methods were used in the investigation. We used diagrams in combination with mean values to make general statements regarding the parameters investigated, and percentage values to show relationships.

In the majority of cases, we used data relating to the drivers only. Where relevant, we also showed data relating to front seat passengers.

All data was based on statements made by the patient or their physician to the insurance company. On this basis, it is important to analyze any statement carefully with regard to potential bias to gain compensation benefits.

RESULTS

TECHNICAL ASPECTS

Change of Velocity

In order to give an impression of the force of impact, Figure 2 shows the mean change of velocity (delta v) in terms of the impact direction.

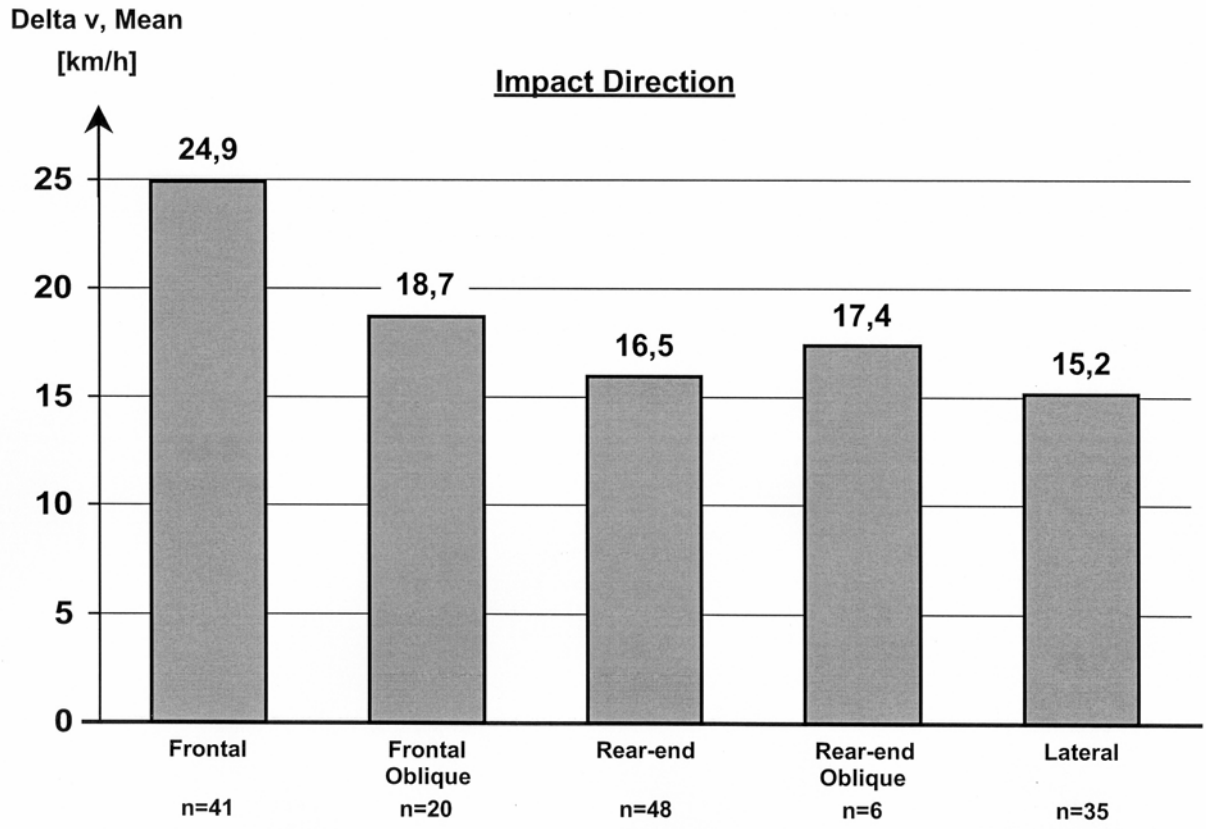

Fig. 2 - Impact Direction and Change of Velocity (delta v)
(Number of Impacts n = 150, each delta v value is result of reconstruction by "PC Crash")

Frontal impacts occurred at a relatively high change of velocity (mean: 24.9 km/h) compared with lateral impacts, which returned the lowest change of velocity in our report (15.2 km/h, mean).

Impact Configuration

Frontal accidents with full overlap were rarely observed (8%), whereas straight (± 30 degree) partial overlap was observed in 30% of cases. The majority of head-on collisions (62%) occurred at an angle.

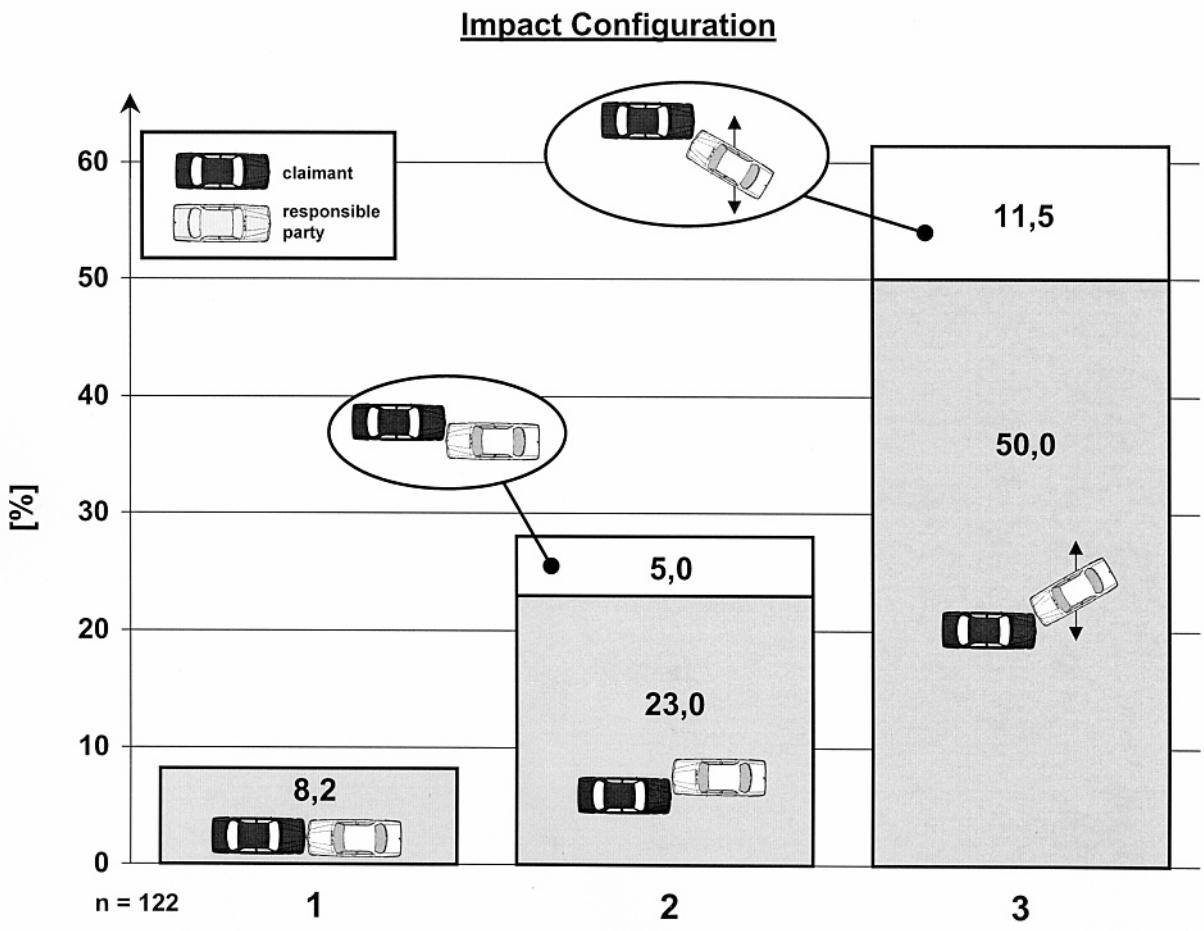

Fig. 3 - Impact Configuration for Frontal Car-Car Collisions with CSD Injury

Rear-end to frontal collisions generally displayed the same configuration as in our previous accident analysis (Hell and Langwieder 1998, 1999 and 2001): Straight collisions with full overlap were observed in 60% of cases. Partial overlap with straight impact direction (± 30 degree) was observed in a third of cases, whereas angled rear-end impacts were identified in only 10% of cases.

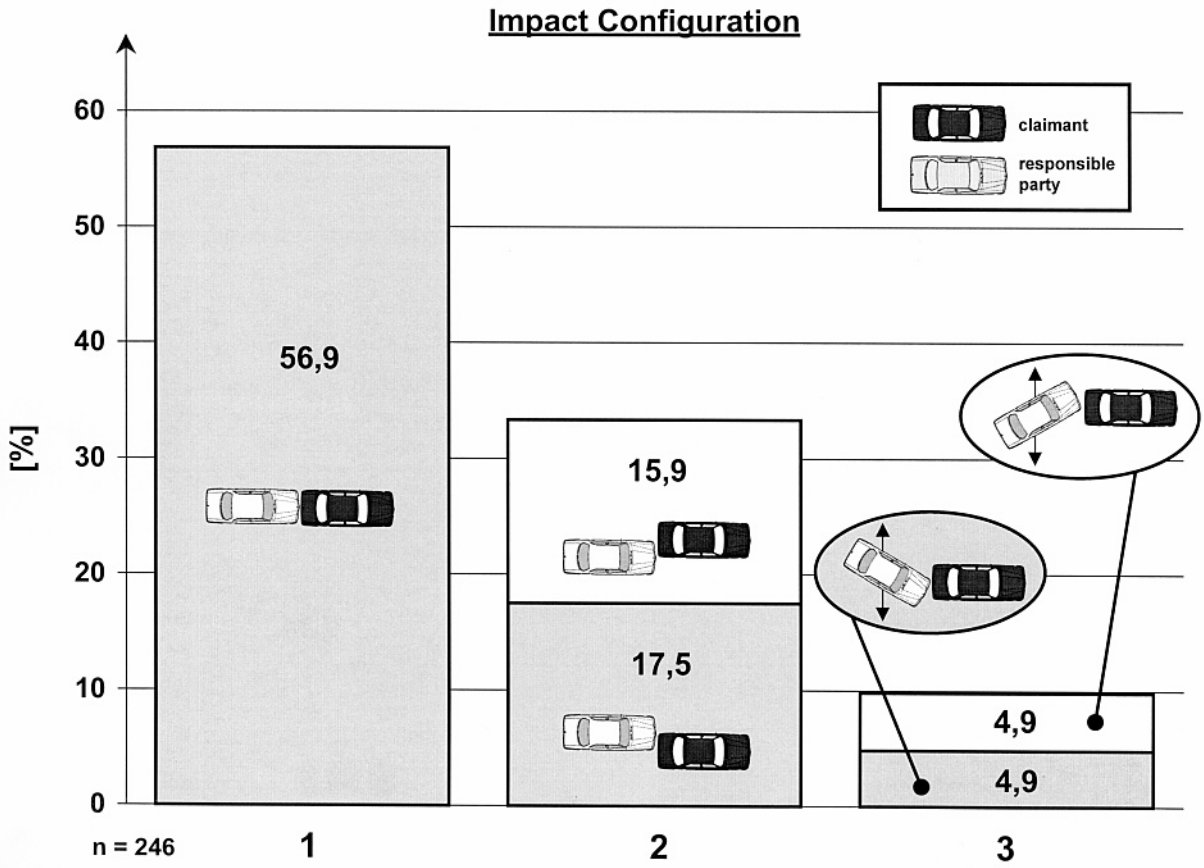

Fig. 4 - Impact Configuration for Rear-End Car-Car Collisions with CSD Injury

To achieve a general overview of the lateral impact scenario, it was necessary to divide the data set into several lateral impact configurations. Approximately 40% of all lateral accidents investigated were collisions into the passenger cell compartment (Table 2). Of these, the number of 90 degree impacts was marginally lower than the number of collisions at other angles.
To allow further differentiation, sideswipe collisions (9.2%) were also addressed separately. In this type of collision, the risk of biomechanical injury is relatively low due to the generally low delta v between the two cars.

Collision area	Number Total	%
Inside the passenger compartment	**69**	**43.9**
Outside the passenger compartment	**90**	**46.9**
Sideswipe damages	**15**	**9.2**
TOTAL	**174**	**100**

Table 2 - Impact Configuration for Lateral Car-Car Collisions with CSD Injury

MEDICAL ASPECTS

Age and Gender

The mean age for both the driver and the front seat passenger was calculated at 37 years, whereas rear seat passengers were on average younger (mean: 26 years).
In our study 57% of drivers were men (and 43% women) but only a third of all front seat passengers were men (66% women). Rear seat passengers were male and female in almost equal distribution.

Injury Severity Score

In order to demonstrate the extent of injury to the car's passengers the "Injury Severity Score" (ISS) was used in our study. The ISS is the sum of the squares of the highest AIS score in three different body regions (Baker 1976).

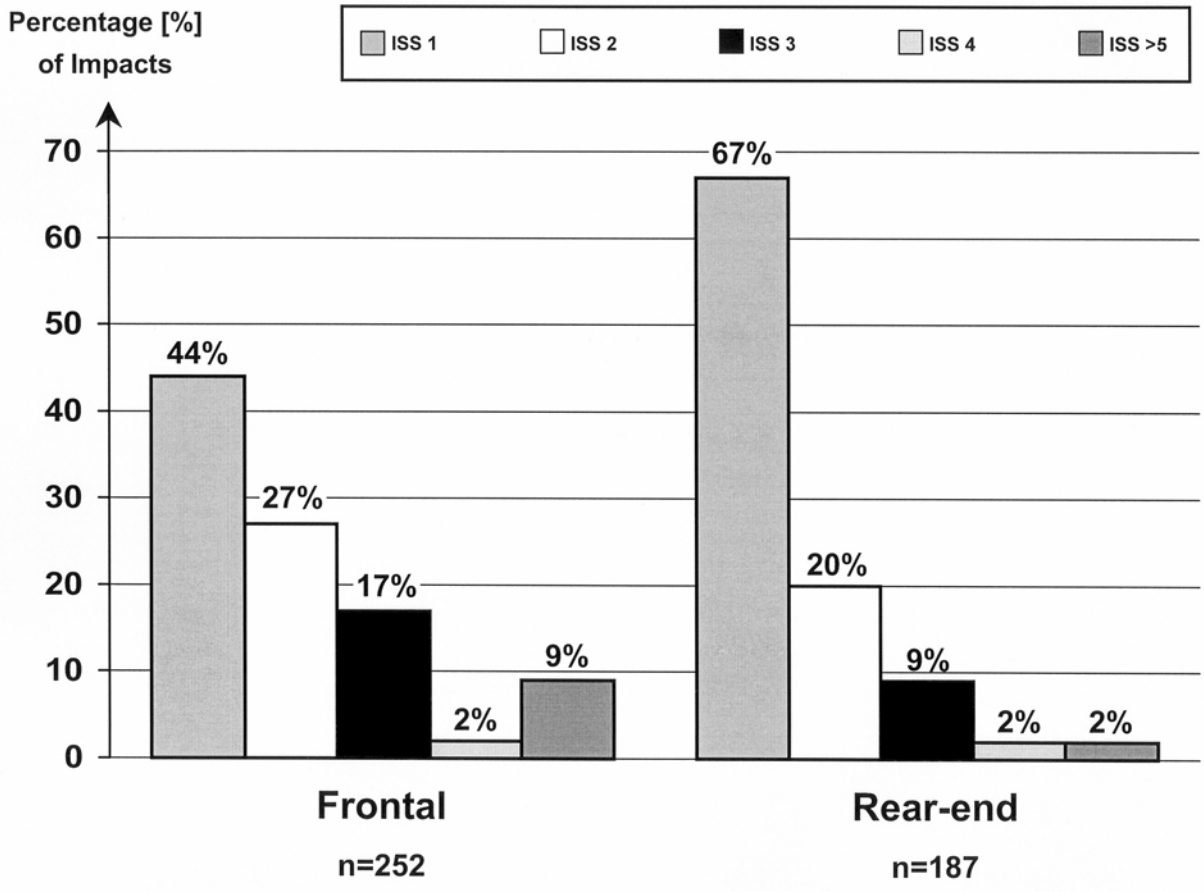

Fig. 5 - Injury Severity Score in Frontal and Rear-End Impacts

Figure 5 illustrates that the extent of general injury was lower for rear-end impacts than for frontal impacts (ISS ≥ 44% versus 11%). Here, CSD injuries (=AIS 1) mostly occurred in addition to minor injuries such as abrasion, contusion or laceration (=AIS 1) to one or two other areas of the body (ISS 2 or 3 respectively).

In lateral collisions (Figure 6), there was no significant distinction in the ISS pattern between the struck and the non-struck side. In general, the majority of the injuries (85%) were rated at ISS 1 or 2, indicating a single CSD injury or CSD injury plus one minor AIS 1 injury (see above) to another area of the body.

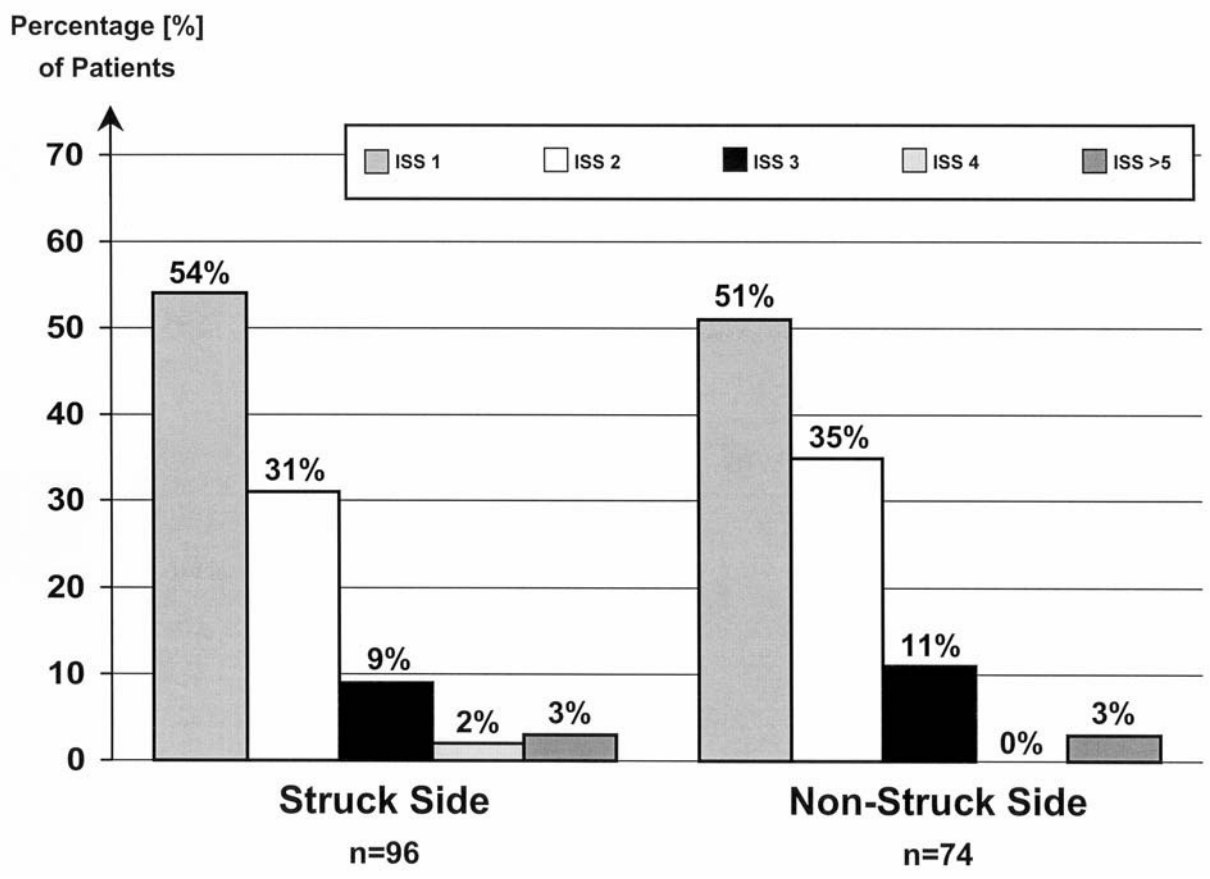

Fig. 6 - Injury Severity Score in Lateral Impacts

QTF Grade

The "Quebec Task Force on Whiplash Associated Disorders" (Spitzer 1995) was introduced as a clear and simple classification scale for cervical spine injuries. The scale is based on the distinction between subjective and objective criteria such as "pain" or "reduced neck movement" and on the incidence of neurological symptoms as shown in Table 3.

QTF Grade	Clinical Features
0	No complaints about the neck, No physical signs
1	Complaints about neck pain, stiffness or tenderness only, No physical signs
2	Neck pain complaints and musculoskeletal signs
3	Neck pain complaints and neurological signs
4	Neck pain complaints and fracture or dislocation

Table 3 - The Quebec Classification of Whiplash Associated Disorders

Comparing our data with the overall distribution of males and females in the driver's position (Statistisches Bundesamt Wiesbaden 2000), revealed that the number of women suffering from a CSD injury of QTF Grade I, II or III was higher than the number of men (Figure 7). The majority (males and females) displayed injuries rated at QTF I (28%) and II (64%). QTF III injuries (neurological symptoms) were seen only in 8% of cases.

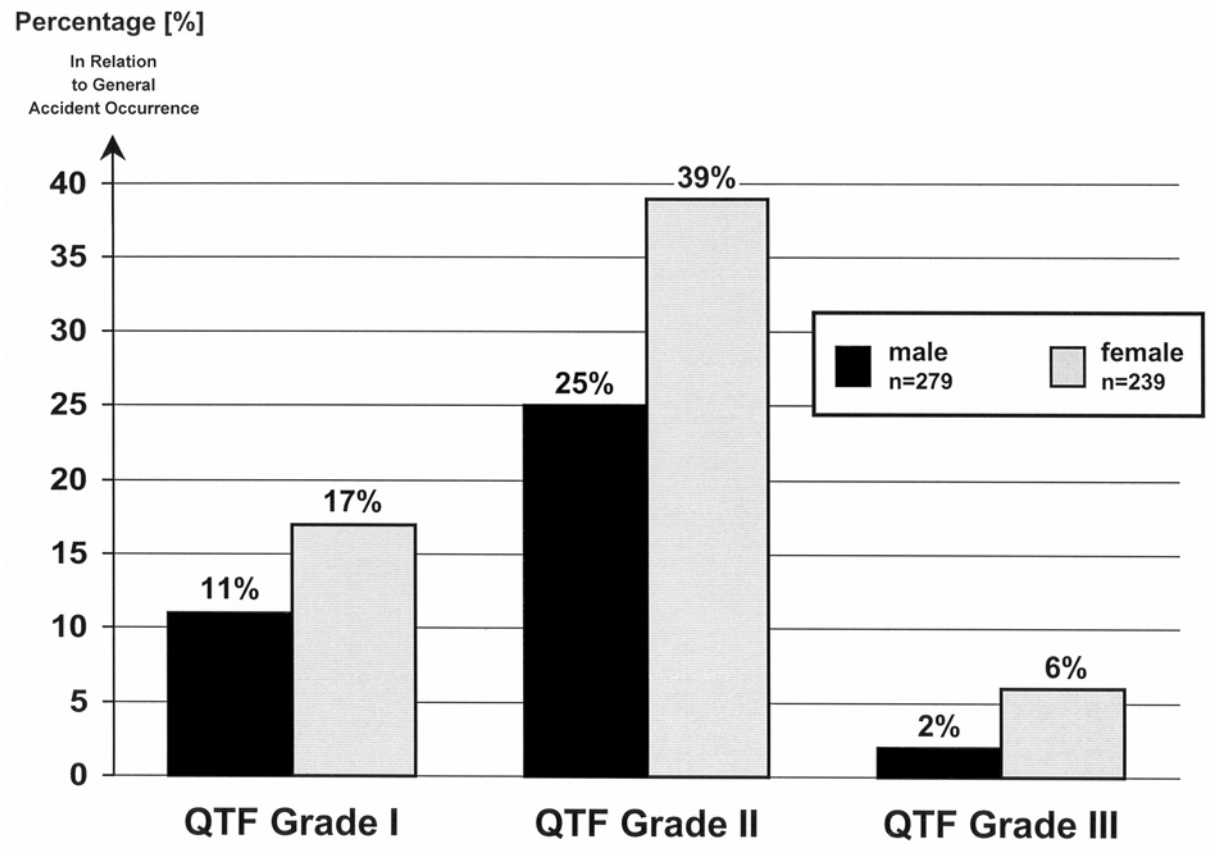

Fig. 7 – Driver's QTF Grade and Gender (n= 518)

For males and females in the front passenger seat (again, in relation to overall accident occurrence) there was no difference in the distribution of injuries rated at QTF Grades I, II and III.

Duration of Treatment

The duration of treatment ranged from 24 hours to more than 6 months. In our sample, 12% of the patients showed long-term symptoms for more than 6 weeks, but only 1% sustained long-lasting symptoms for more than 6 months. One significant group of patients (16%) went to consult a physician and had treatment completed within 24 hours. 20% of patients received treatment for 1-2 weeks and 30% for 2-6 weeks (Figure 8).

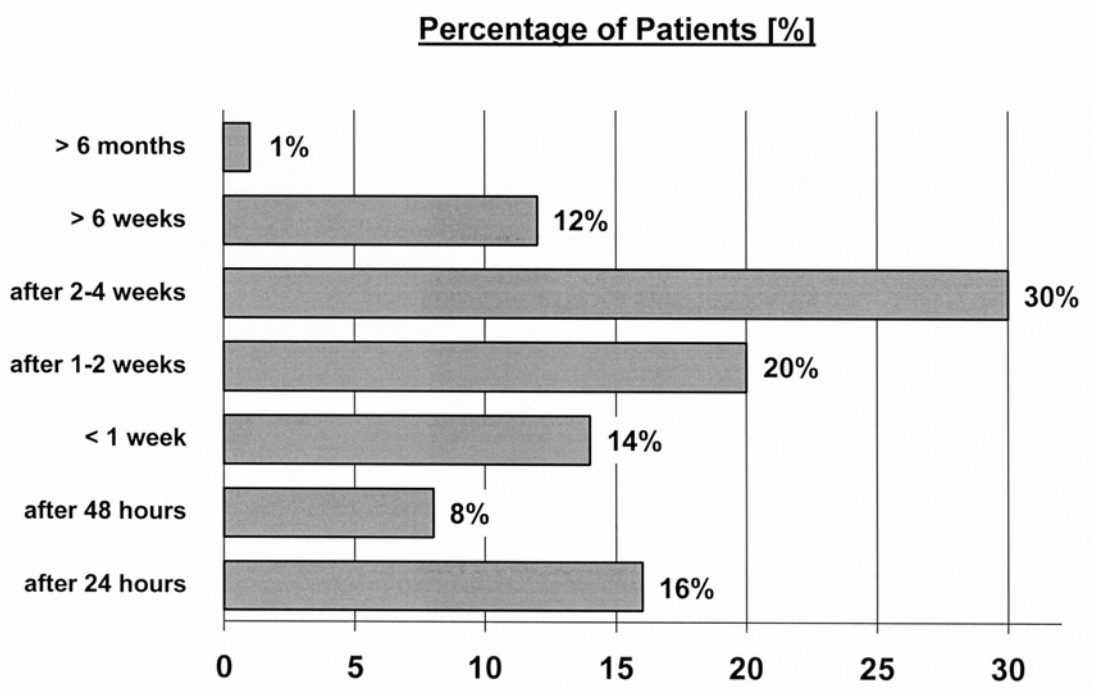

Fig. 8 - End of Treatment (n= 572)

Figure 9 shows that the older the patients were, the longer the treatment lasted (18-25 years: 77% less than 2 weeks and 2% more than 6 weeks, 56-65 years: 51% less than 2 weeks and 8% more than 6 weeks).

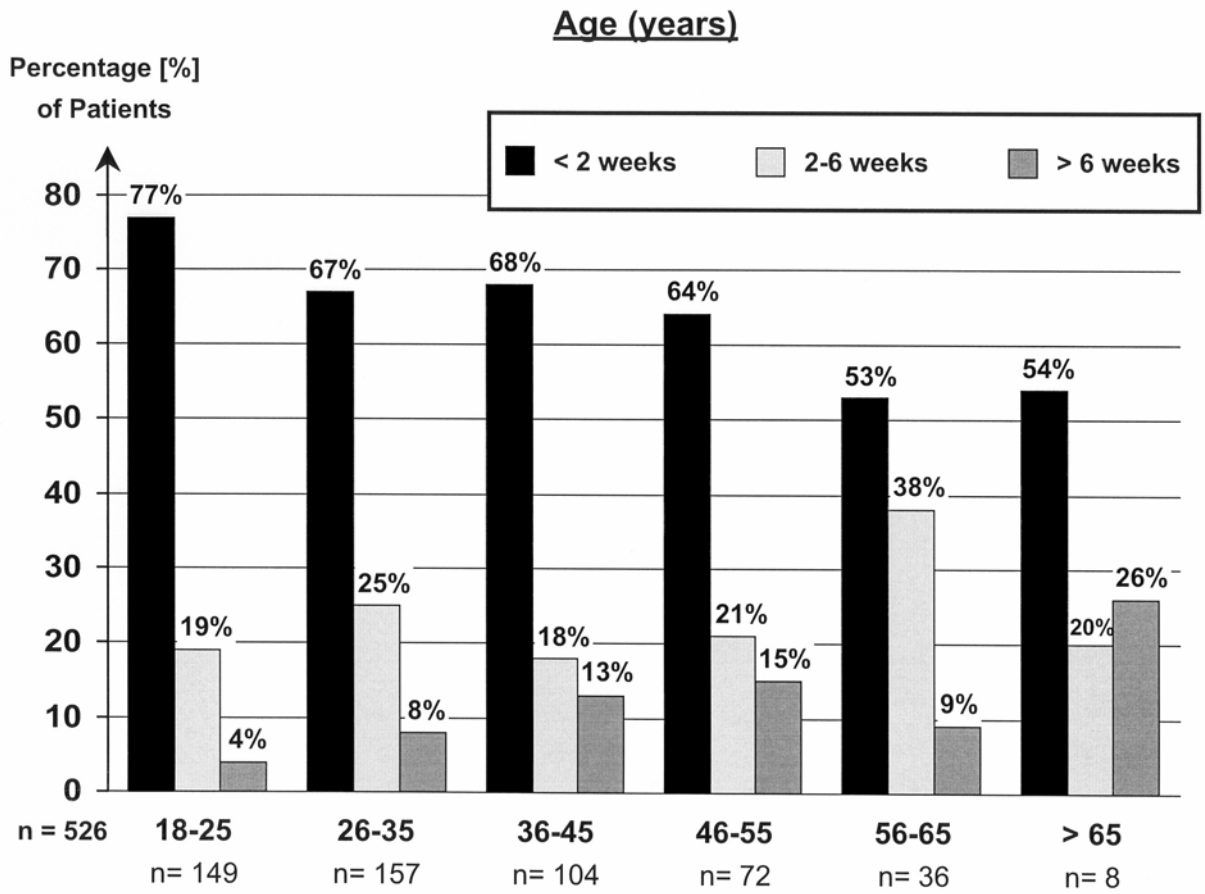

Figure 9 – Duration of Treatment

Figure 10 shows that there was a clear correlation between the QTF injury grade and the length of absence from work. Patients with QTF Grade III were absent from work for more than twice as long (23 days) as QTF Grade I patients (11 days).

By examining the sex of the patients, it can be seen that 12 % of females were absent from work for more than 6 weeks (males: 5%).

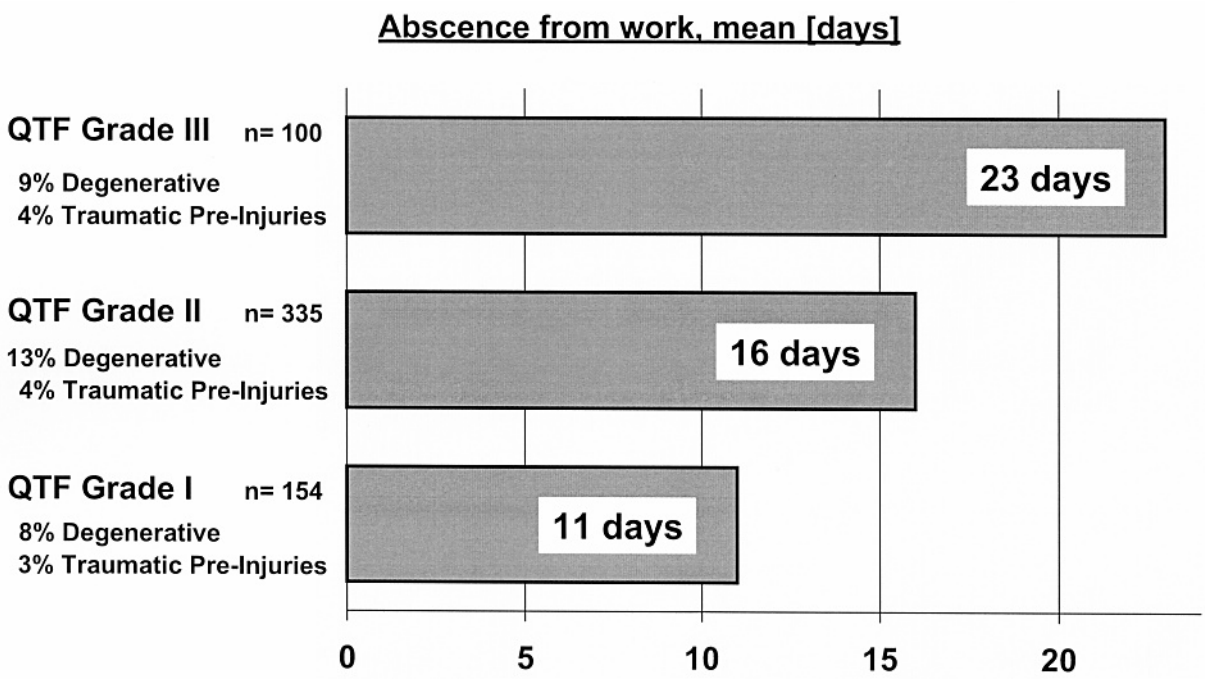

Fig. 10 - QTF Grade and Absence from work

REAR-END IMPACT / CAR TYPE PERFORMANCE STATISTICS

Around 300 000 cases from the HUK Coburg Insurance Statistics were selected on the basis that damage had been caused to the car's rear-end, to allow analysis of rear-end accidents. The objective was to determine whether certain cars cause lower CSD injury rates in rear-end impacts (Muser 2003) than others in the same weight class. Cars with uninjured passengers were also included in this investigation. Although construction of the database is still in the early stages and more data should be added, the initial results can be released (Table 4).

To simplify the evaluation process, the car models were divided into three groups: good, medium and poor rear-end accident performance. Our results were compared with material from Folksam insurance (Kullgren 2000 and Krafft 2002). In many cases the two sets of injury statistics returned comparable results. Cars in the same weight class demonstrated wide-ranging levels of protection against CSD injury: In our study, i.e. out of 258 registered accidents where the damaged vehicle was a particular model, 96 were rear-end collisions. Of these, 13 passengers sustained CSD injuries, one suffered long-term injury (over 6 weeks). In terms of the risk per 1000 collisions, this represents a rate of 135/1000 for all whiplash-associated disorders and a rate of 10/1000 for long-term injuries. For a model that is comparable in terms of weight and car construction, 252 collisions were registered, of which 64 were rear-end collisions and 21 passengers were injured, 10 sustaining long-term CSD injury. For a comparable car, this signifies a rate of 328/1000 injuries and 156/1000 long-term cases.

Injury rates at rear-end collisions divided by Manufacturer and Type ("Long Term Injuries" , Over 6 weeks)

Statistics HuK Coburg 2000 damages

Manufacturer	Weight Class	No. Accidents with Car Damage	Rear-end coll. Total	with injured		Long Term Injured > 6 weeks		
				No.	per 1000	No.	per 1.000	
B - France	Lower Middle Class	258	**96**	13	*135*	1	***10***	good
C - Germany	Upper Middle Class	251	**90**	14	*156*	2	***22***	
D - Germany	Small Car	170	**65**	16	*246*	2	***31***	
E - Germany	Upper Middle Class	198	**80**	18	*225*	3	***38***	
F - Germany	Lower Middle Class	378	**152**	39	*257*	8	***53***	medium
F - Germany	Middle Class	210	**112**	20	*179*	6	***54***	
G - Germany	Middle Class	131	**52**	12	*231*	3	***58***	
H - Germany	Upper Middle Class	512	**173**	35	*202*	11	***64***	
G - Germany	Lower Middle Class	1087	**391**	115	*294*	25	***64***	
D - Germany	Middle Class	492	**211**	44	*209*	14	***66***	
G - Germany	Lower Middle Class	523	**203**	88	*433*	18	***89***	poor
F - Germany	Middle Class	437	**191**	52	*272*	18	***94***	
G - Germany	Lower Middle Class	229	**79**	30	*380*	8	***101***	
E - Germany	Lower Middle Class	177	**45**	18	*400*	7	***156***	
B - France	Lower Middle Class	252	**64**	21	*328*	10	***156***	

Table 4 - GDV Good, Medium and Poor Performing Cars at Rear-End Collision

DISCUSSION

TECHNICAL ASPECTS

As regards the "change of velocity" parameter, it is necessary to mention that the reconstruction process contains a number of calculation transactions that may have influenced the outcome.

Compared with other studies (Morris 2000 and Krafft 2002), the results show that the delta v for frontal impact collisions where CSD injuries were caused is much higher (average 24.9 km/h) than for rear-end impact collisions (average 16.5 km/h) and lateral impact collisions (15km/h). This could be explained by the higher range of movement of the head and torso in frontal collisions where the lower limit of the speed at which neck injury is caused appears to be higher than in rear-end collisions.

In lateral collisions this study does not define whether or not head impact occurred against the B-pillar. Thus, cases with very low delta v and resulting head/neck injuries were also included. Ideally, cases involving head impact and purely lateral head/neck movement should be separately evaluated.

MEDICAL ASPECTS

If one takes into account that cases were only selected where at least one person in the claimant's car had sustained CSD injuries, we must assume that slight impact collisions (where no passengers were injured) have been neglected. It is likely that moderate impact scenarios tend to be overrepresented in the data resources. On the other hand, it is also known that patients with major injuries tend to disregard their cervical spine distortion complaints.

Information on medical care is based on questionnaires completed by the physician treating the injuries. All statements given by the physicians lack objectivity and depend on the qualifications and specialism of the respective physician. Many indications tend to favor the value of the patient's insurance company compensation.

With regard to the longer recovery process for older people, it is necessary to note that the number of additional – often degenerative – complaints is higher for this group of patients than it is for younger people. These "pre-injuries" may prolong the recovery period.

The fact that the number of women with CSD injuries Grades I-III is higher than the number of men could be not only a sex-related phenomenon but could also imply that women are more sensitive to their complaints and more likely to seek help than men. From this data set, only 1% of long-term

injuries were treated over a period of 6 months, which is contrary to the results of many investigations in other countries, where higher long-term rates were observed.

REAR-END IMPACT CAR TYPE PERFORMANCE STATISTICS

Although our database should be expanded and optimized in future, clear differences can be observed between the results for unhurt passengers, passengers that sustained CSD injuries and those suffering long-term injury in vehicles of the same weight class. A correlation between long-term injury risk and overall CSD risk cannot be observed in all cases. Despite the fact that here again data could be biased by a desire for insurance compensation, it is still worth mentioning that the Swedish Folksam and GDV results appear to be generally comparable. The effect mentioned above may have been neglected.

The effect of the weight of the other car involved has not been taken into account. This parameter may influence the performance outcome. A larger database may allow more confident statements on this issue.

The better performance of particular car models in rear-end collisions with regard to the occupants' CSD recovery period (long-term treatment) could be put down to higher quality protection equipment and safety systems inside and outside the car, but could also be influenced by factors such as crash severity, the number of occupants in the car or the age and sex of the patient.

CONCLUSIONS AND OUTLOOK

Despite the fact that the data material is based on subjective estimations made by the physicians treating the injuries and their impartiality, it would nevertheless appear that a large proportion of injured car drivers with cervical distortion suffer genuine symptoms that cannot be overlooked.

On the basis of our study, it can be seen that these symptoms can be treated in approximately 1-4 weeks.

Bearing in mind that female patients with cervical spine distortion caused in car accidents undergo treatment for longer periods and that they suffer a larger proportion of injuries rated at Grades I, II and III, it is impossible to make general statements without qualifying them on the basis of gender.

The fact that women represent the higher percentage of CSD patients might be related to their smaller neck circumference and thinner muscular system in the neck. Special attention should be paid to the posture of women when sitting in the driver's position. Hyperextension mechanisms during impact may be caused by the fact that women display a particular tendency to pretension, where men do not.

To enable more detailed analysis, risk curves should be produced for each collision type (frontal, rear-end, lateral right and lateral left) and for each seating position according to both gender and age.

The range of medical treatment for CSD injuries and their symptoms demonstrates the clear need for official instructions on the treatment of whiplash injuries.

The number of people suffering long-term CSD injuries after rear-end collisions should be analyzed in greater detail, taking into account not only the car model involved but also the severity of the crash, the number of car occupants and the age and sex of the patients, in order to make general statements possible.

Lateral collisions should be analyzed further in terms of the parameter "with or without head impact".

Future guidelines for prevention of CSD injuries should focus not only on rear-end collisions, but also on frontal collisions (airbag, belt pretensioner) and even lateral collisions (head airbag).

Frontal tests should in future focus on oblique impact scenarios with a delta v of at least 25km/h.

It might be of considerable interest in future to evaluate the relevance of "good, medium and poor" performing car models in real-life accident scenarios on the basis of a representative and expanded database. It also appears to be essential establish whether frequency of CSD injuries can to a significant extent be avoided by improving safety systems and developing seat design.

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