REPORTED SOFT TISSUE NECK INJURIES AFTER REAR-END CAR COLLISIONS

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ABSTRACT

Soft tissue neck injuries or cervical spine distortion injuries (CSD) are dominant injuries in all claimed car collisions. The injury mechanisms are currently not fully understood because some symptoms are rated subjectively and even modern radiological imaging techniques (CT, MRI, PET etc.) can not detect structures damaged. A first attempt was made using the new internationally accepted QTF (Quebec Task Force) classification on CSD injuries to differentiate between three grades of this minor (AIS 1) injury within a large retrospective insurance data material, which covers 15.000 car to car collisions with injured occupants in Germany. From this sample 517 rear-end collisions have been analysed medically and technically in order to get an overview about the real accident scenario. The task of this investigation is to identify risk factors, population at risk and to define countermeasures against this epidemic injury, which can also cause long-term problems.

THE COMPARISON OF MAJOR ACCIDENT SAMPLES from the German Motor insurers shows that the incidence of cervical spine injuries in Motor Vehicle Accidents have almost doubled in the last 20 years. (Figure 1).

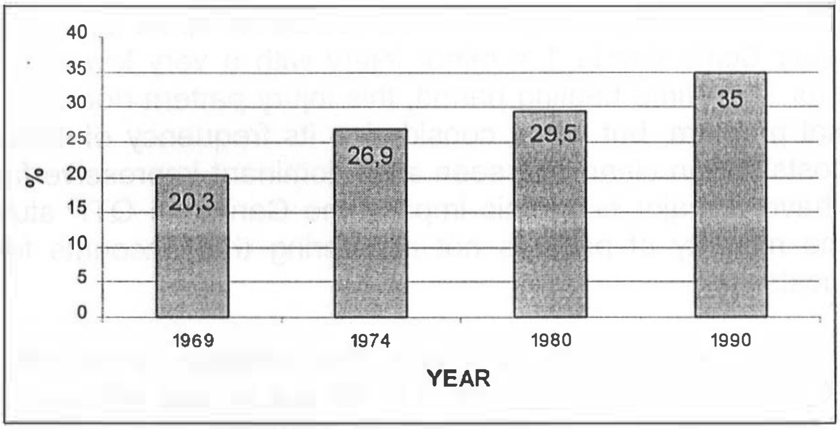


Figure 1: Percentage of CSD injuries in Car Accidents in Germany per injured Person (GDV accident material, injury frequency per body region, all collision types)

The assumed socio-economic losses for rear-end collisions in Germany (calculated after German Injury Cost Scale [1]) would amount up to 2 Billion Marks, that means about 1100 MECU only for rear-end collision cases for the year 1990 in the old Federal Republic of Germany [2]. For 1997 a higher amount can be assumed because of increased incidence (reported from German insurers) and the inclusion of former East Germany. Estimations in other countries were for The Netherlands 150 MECU, for Sweden 210 MECU and for Canada (only British Columbia) 450 MECU. US estimations [3] were 10 billion $ per year.

It must be remarked that international incidence statistics vary significantly due to different insurance compensation systems and the financial amount of compensation for the injury: For example the incidence rate of CSD injuries per 100.000 inhabitants varies from 70 in East Canada (Quebec) vs. 700 in West-Canada (Saskatchewan). The Quebec Task Force Study for whiplash associated disorders came to the result that a possible explanation for the major difference in two Canadian provinces is a different insurance compensation system, where East-Canada uses a no-fault system in comparison to the West-Canadian tort system [4]. Other published incidence rates vary from 100 in Australia, 200 in Norway and 380 in USA all per 100.000 inhabitants but surveyed in different years and different materials (accident incidence and insurance compensation claims so that the material is not really comparable) [5].

The incidence of CSD in the material investigated here is lower compared to other countries but the analysis deals only with insurance material in which many of the cases had been financially compensated and in which most of the policy holders have not been responsible for the collision.

In the year 1990 in Germany (former territory of the federal republic), in about 54% of all car-to-car accidents with personal injury the accident pattern was a rear end collision [6, 7, 8]. The in comparison to other accident materials relatively high number of rear-end collisions could be explained through the report from insurance material. Police report based statistics show an under representation of CSD accidents, because of the fact that many CSD injuries are reported days after the accident and are therefore not prominent in official statistics. An estimation based on the insurance statistics in Germany came to about 200.000 reported cervical spine injuries after rear-end collisions for the year 1990 only in former Western-Germany. As most cases of cervical spine injury are classified AIS 1 (Abbreviated Injury Scale Grade 1 = minor injury with a very low risk for fatality) and show a tendency for short time healing period, this injury pattern does not seem to be an impressing medical problem; but when considering its frequency of occurrence and the socio-economic costs, it can clearly be seen as a dominant impressive factor. Especially long term cases have a major economic impact: the Canadian QTF study came to the result that it is the minority of patients not recovering that accounts for an inordinate proportion of the costs [4]

The typical CSD injury mechanism in a rear end collision is described in previous publications [9, 10, 11, 12, 13, 14, 15, 16, 17, 18] but is also influenced by seat back geometry and elasticity, horizontal and vertical distance and various other human variations (height, weight, age, sex, pre-damage of the spine etc.).

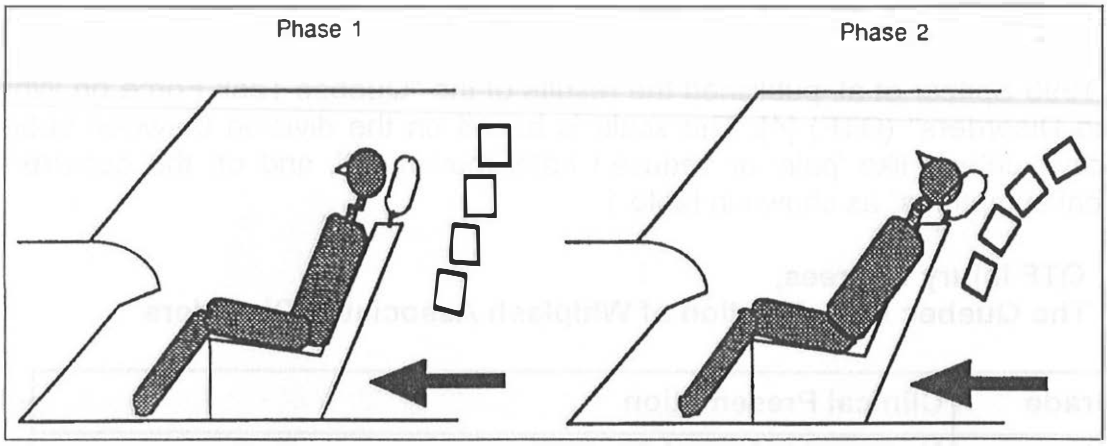


Figure 2: Injury mechanism after rear end collision. Source: Walz [19]
(Phase 1: head translation; phase 2: neck extension)

In general, it can be said that the exact anatomic lesion of CSD very often is not found. According to Spitzer [4], the occurring symptoms are the consequence of soft tissue injury of the neck structures. As shown in animal models, recovery can be divided in several healing phases: While the first phase of acute inflammation and reaction lasts less than 72 hours, the second phase of repair and regeneration may last from about 72 hours up to six weeks, and the final recovery phase can last up to one year. This means an estimated healing period of 4 to 6 weeks in cases of Whiplash Associated Disorder with partial tear of soft tissues [4] In the cases with neurologic symptoms, the recovery can be prolonged, as the characteristics of nerve injuries are very often different from those of soft tissue injuries.

THE PROBLEM OF OBJECTIVE DEFINITION OF CERVICAL SPINE DISORDERS

The term "whiplash" is misleading and biomechanically incorrect. It presumes a virtually non-existent two-phase back-and-forth movement of the head like the cracking of a whip, in a rear-end or - vice-versa - a frontal collision [12].

Due to the large number of clinical manifestations, and as there is currently no possibility to objectify the symptoms by X-ray/MRI or other clinical findings, often a gap between the patients complaints and concrete measurable symptoms exists. There have been improvements establishing different kinds of ranking systems, but past experience have shown that there was no continuity in classifications among the different questionnaires. Thus, a basic classification, which could be used for most cases using the diagnosis of objective or not objective criteria and neurologic deficit, had to be found.

QUEBEC TASK FORCE INJURY CLASSIFICATION

In March 1995 Spitzer et al. published the results of the "Quebec Task Force on Whiplash Associated Disorders" (QTF) [4]. The scale is based on the division between subjective and objective criteria like 'pain' or 'reduced neck movement', and on the occurrence of neurological symptoms, as shown in table 1.

TABLE 1. **QTF Injury Degrees,**
The Quebec Classification of Whiplash Associated Disorders

Grade	Clinical Presentation
0	No complaint about the neck No physical signs
1	Neck complaint of pain, stiffness or tenderness only No physical signs
2	Neck complaint AND Musculoskeletal signs
3	Neck complaint AND Neurological signs
4	Neck complaint AND Fracture or dislocation

For the staging at second degree, limited range of motion and point tenderness were accepted (objectified by the physician); third degree staging included decreased deep tendon reflexes, weakness and sensory deficits.
The suspected pathology for different QTF grades is estimated as follows:

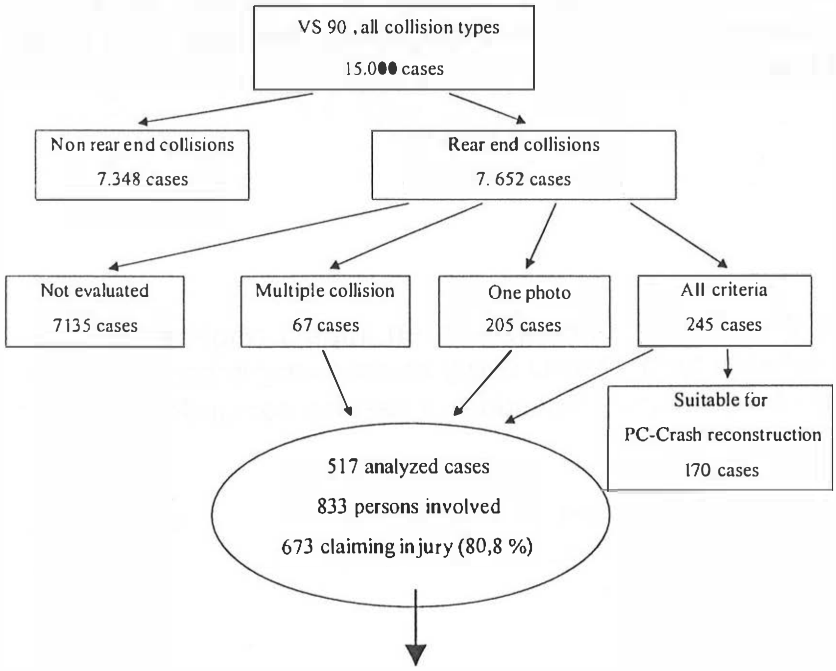
TABLE 2. **Pathology of CSD**

Estimated Pathology of Different QTF Degrees	
QTF 1	Microscopic or multi-microscopic lesion Lesion is too small to cause muscular spasm
QTF 2	Distortion and soft tissue bleeding (joint capsules, ligaments, tendons and muscles). Secondary muscle spasm after soft tissue injury
QTF 3	Injuries of the neurologic system caused by mechanical damage or secondary irritation caused by bleeding or inflammation

MATERIAL AND METHODS

CASE SELECTION

All 15.000 GDV Vehicle Safety-90 cases (18% of all car-car collisions with injuries from the year 1990 in West-Germany) were screened to find out defined cases with: rear-end collision, single impact, claimed cervical spine injury (CSD), good medical documentation and photos of both cars involved.



MATERIAL OF SAMPLE

A total number of 245 cases could be found to fulfil all criteria. By means of the "PC-Crash" computer program further information about the accident pattern and velocity change parameters of 170 cars was gained.

In addition, another 205 cases with only one photo available (and thus only limited possibility of PC reconstruction) and 67 multiple collision cases underwent the same analysis, especially concerning the medical data. Finally, a total number of 517 cases of rear-end collisions with altogether 833 persons involved, 673 (80,8%) of them claiming injury, could be investigated.

The advantage of the VS-90 retrospective insurance chart sample is its size, proven to be representative, with the accidents distributed homogeneously according to the real accident distribution in Germany (Former territory of the federal republic).
Of course, some disadvantages must be taken into account as well: The presence of only claimants in the data material may lead to a certain "insurance bias", including the danger of aggravation or even unjustified claims because of the financial attraction of the compensation. It is important to remark that all reported injuries were taken into the sample. The proportion of aggravated cases in which the reported symptoms are not or only partly accident related could not be identified here since only limited injury information was available.

In order to check the material about inhomogeneous distribution within different parameters, age was correlated with delta v, where a possible shift of higher age and lower delta v could be expected which might affect the general analysis. It was found out that age versus delta v was equally distributed in all age classes, so that the material is expected to be homogenous.

In a former study [10, 15] possibly aggravated CSD because of implausible delta v and/or insufficient medical documentation was estimated to be about 50% in the German Insurance material. The North American Insurance Institute [3] came to about 30-40 % implausible cases which indicates the problem of the whole data sample in low but sometimes also in higher delta v regions because of insurance compensation expectancies. Therefore new medical diagnostic methods for a better validation of CSD have to be worked out in the future.

RESULTS

ACCIDENT

With over 85% the straight collision with an impact angle under 5% is representing the most frequent collision type. Nearly every second rear impact happens at an overlap of 81 to 100%. For a standard test procedure it can be concluded that this collision geometry would be representative.

The most frequent impact speeds of the striking car in a rear-end accident with reported CSD injuries lie between 9 and 45 km/h (see Figure 3).

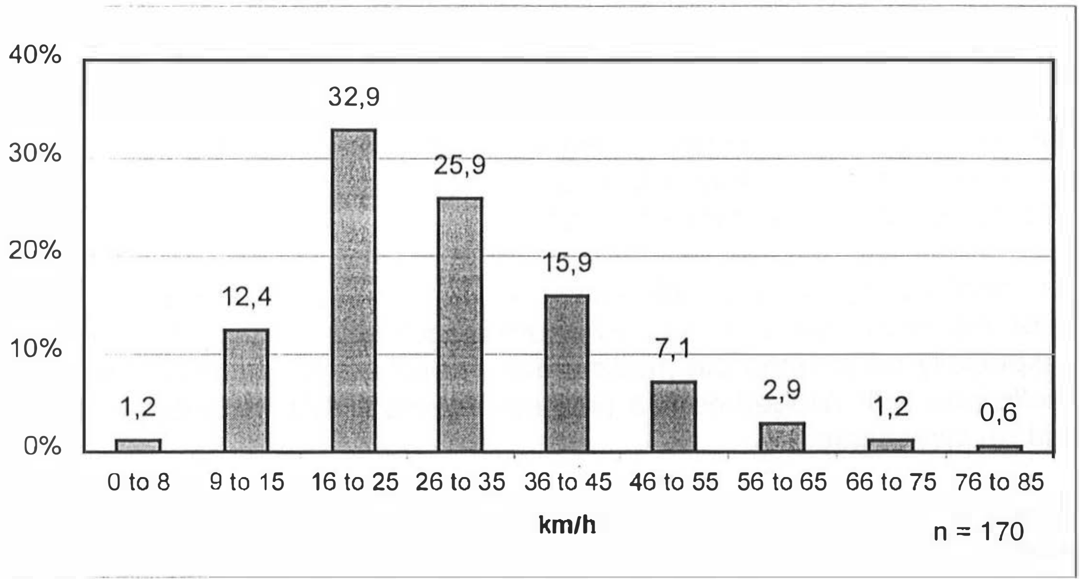


Figure 3: Distribution of impact speed (striking car)

The delta v measures the velocity change of the vehicles` centre of gravity, from the moment of the beginning until the end of the collision, stated in km/h (Fig. 4, 5). Due to current knowledge reported injuries at a delta v up to 15 km/h were suspicious for possible injury aggravation and tended often not to be compensated in the last years in Germany. The material shows the need for better objective diagnostic measures of CSD injuries, otherwise the research material is always biased with aggravated cases. A higher plausibility of injury could be seen over 15 km/h delta v, although some passengers in real accidents with a significantly higher velocity change remain uninjured. In a former study [10,15] the amount of implausible and/or insufficient medically documented cases was estimated with around 50%.

The data analysis shows that the number of claimed QTF 3 injuries were divided among the Delta v groups up to 25 km/h (Figure 4). Again it has to be reflected that in this material a possibly high proportion of implausible injuries is included. Aggravated injuries could be even found in higher delta v regions > 15 km/h, because sled tests with volunteers and in-depth accident analysis present also cases with no injury at significantly higher velocities. Nevertheless a high proportion of real CSD injuries could be found with the highest probability in delta v groups over 15 km/h. Surprisingly at higher velocities the amount of high graded QTF degrees disappear and the number of uninjured occupants is growing. In future research this controversy should be analysed in detail. Possibly, a significant backward movement of the seat back at delta v higher than 25 km/h is responsible for this paradox.

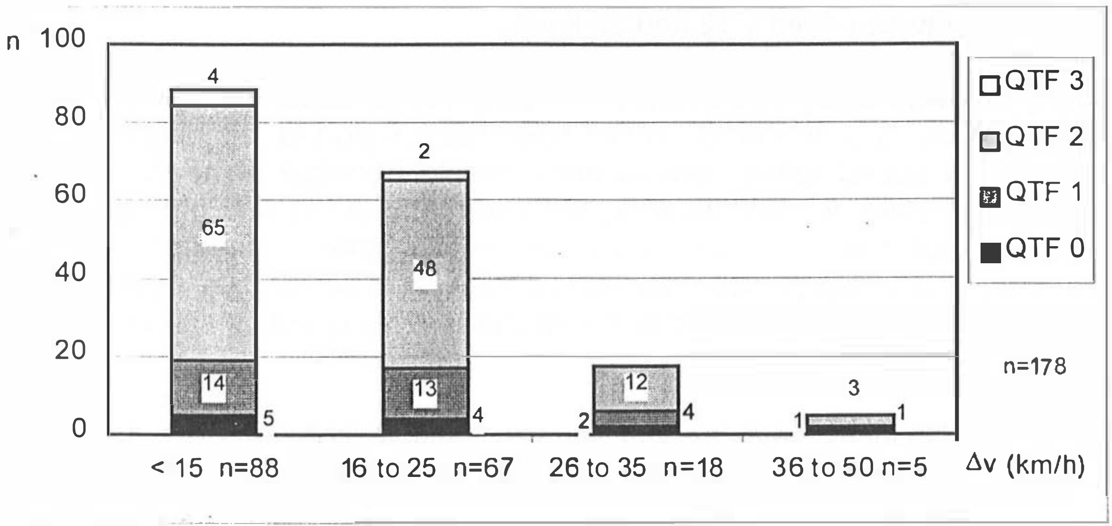


Figure 4: QTF injury degrees in different Delta v groups
"Reported" injuries of Insurance claimant material (car occupants)

Generally low velocity change collisions (delta v up to 15 km/h) dominate the sample with 53%. The QTF III injuries at delta v 15 km/h are correlated with non-objective symptoms like paresthesia and therefore scientifically not justified. Medium severe (delta v 16-25 km/h) accidents could be observed in 35%, whereas higher speed accidents (delta v over 25 km/h) occurred in only 11% (see Figure 5). Because only rear-end collisions with reported CSD injuries have been reconstructed no comparison between rear-end accidents with no CSD injuries could be made. This should be cleared up in further investigations.

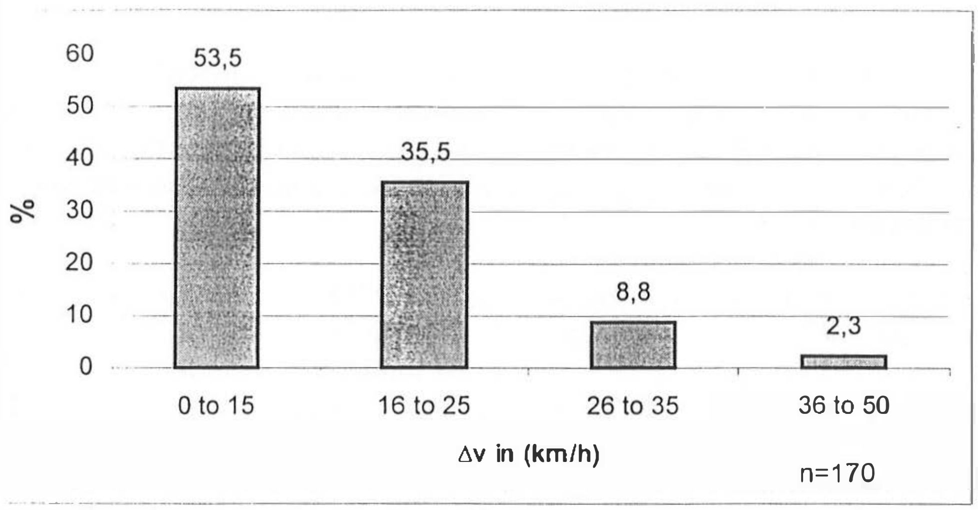


Figure 5: Distribution of Delta v (struck car)

It could therefore be concluded that the main problem area of CSD injuries is related to 10-15 km/h where further research (volunteer tests, dummy development) is rather important. The most beneficial range for testing improved seat and head restraint designs is approximately between delta v 12 and 25 km/h.

Unfortunately no lower injury limit of CSD injuries could be observed, because also in the lowest delta v group QTF II and III injuries have been reported, although most reported injuries in this low speed region remain questionable because of no verification in the current volunteer testing. It could be assumed that many of the QTF II and III patients in the low delta v group have not accident related cervical spine problems i.e. degenerative changes of the spine, although this could not be verified in the medical reports because of limited information in the retrospective accident charts. This question should be cleared up in future investigations.

No increase of QTF injury severity was seen in multiple collisions (n= 155, secondary impact after rear impact) versus a single car to car rear end impact (N= 457).

OCCUPANT CHARACTERICS

The age distribution of occupants with CSD was similar to the total group of occupants with minor injuries in general. A significantly increased proportion of 27,4% is suffering from CSD within the age group 18- to 24-aged, while this group represents only 15.9% of the distribution in normal traffic but also with a higher accident rate (31,5% of minor injured car occupants are aged 18 to 24). On the other hand, the rate of CSD and minor injuries in the age groups over 30 years is lower than their distribution in traffic. For example 32,2% (17,8%) of all occupants with cervical spine distortion lie in the age group of 25 to 39 (40-59) while their representation in traffic lies at 33,0% (38,1%).
When compared to the QTF injury degree, the distribution shows that remarkably most injuries in the < 30 age group are QTF I to II injuries. The highest relative risk for suffering from a QTF III injury is, as expected, in the age group of 60 and older. It has to be taken into account that older people generally show significantly more spine related neurologic and degenerative signs; therefore it appears that non-accident related effects influence particularly this older group. Although the distribution of male and female claimants in the

data material is nearly equal in absolute numbers, women suffer in a 1.4 times higher rate from CSD because of their smaller percentage of participation in traffic according to data from AWA [18].

Most CSD injuries were associated with a very low Injury Severity Score, which ranks from 1 to 75 (see figure 6). It is an unsolved phenomenon that CSD injuries were rarely seen in combination with more severe injuries (fractures).

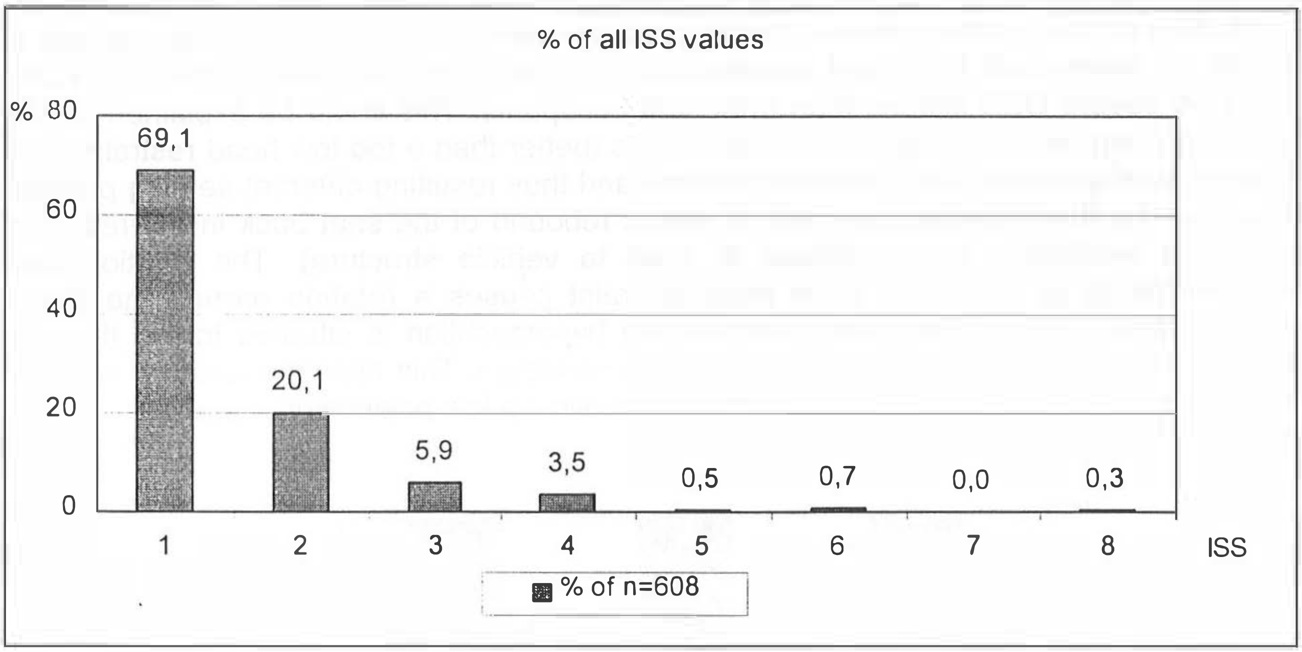


Figure 6: Distribution of ISS values

TABLE 3: **Days of work absence and until full recovery after isolated cervical spine injury**

	WORK ABSENCE		
	Median	Average	n =
QTF 1	7	16	21
QTF 2	19	14	76
QTF 3	12	25	4

FULL RECOVERY		
Median	Average	n =
18	26	20
25	33	62
38	46	3

The period of incapacity shows a clear dependency with QTF injury severity. A more detailed analysis especially about QTF 3 cases, where full recovery could possibly not be reached within a certain (insurance chart) time limit should be investigated in more depth.

The relatively high rate of 18.8% having not reached full recovery within 49 days seems to be probably a "selection effect" of the data material. In many cases the duration until full recovery was not mentioned, as the healing process was not finished at the date of the last (which often was the first) consultation of the testifying doctor. The 127 cases with known recovery date represent the better documented patients more than the "trivial" ones, and thus include a higher number of longer lasting cases. A detailed analysis of long term cases should be performed in another study based on the results of this evaluation.

VEHICLE PARAMETERS

SEATING POSITION

In order to eliminate the influence of shorter height of children sitting in the back seat, which could shift the average QTF degree towards lower rates, only occupants over 16 years age were taken into consideration.
A similar distribution as the results of the head restraint adjustment can be seen at the distribution of CSD on the different seating positions within the struck car. While the rate of injuries of drivers and front seat passengers is similar, the occupants in the rear suffer from less severe CSD injuries than front seat occupants. This could be explained by the mostly missing head restraint on the back seats (better than a too low head restraint!), by different seat geometry with different stiffness and thus resulting different seating position as well as by the advantageous lack of elastic rebound of the seat back in the rear (i.e. Limousine seat-back from backseat is fixed to vehicle structure). The rotation axis (hypomochlion) at a too low fixed head restraint causes a rotation around the upper cervical spine. Without any head restraint the hypomochlion is situated in the thoracic spine, where a higher injury tolerance could be expected. This aspect should be covered in future head restraint designs which should not allow a low positioning.

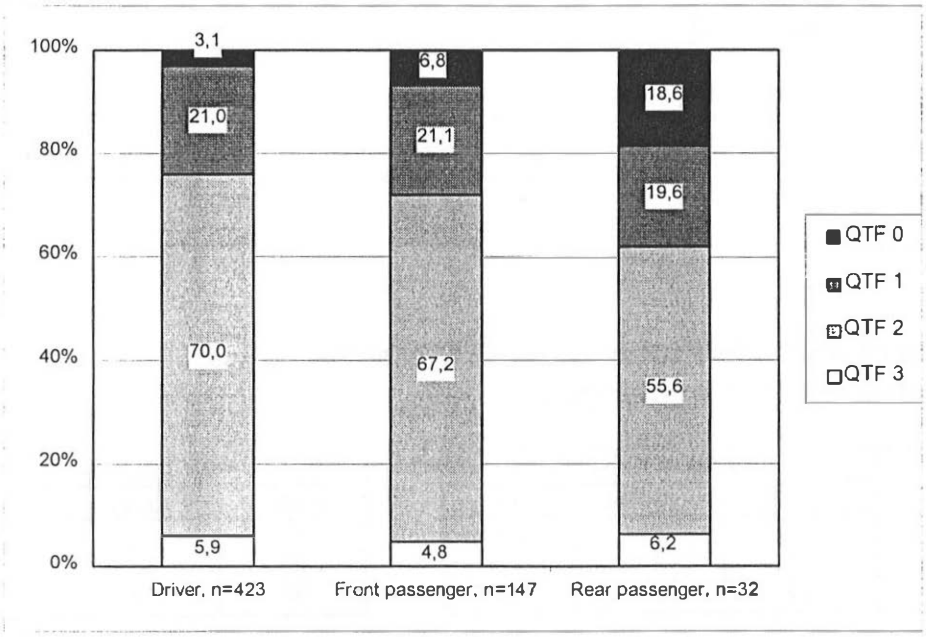


Figure 7: Seating position and QTF Injury Degree
(Occupants older than 16 years, n=602)

HEAD RESTRAINT POSITION

In most cases analysed retrospectively, there was no information about seat or seat back positions at the time of the impact. Nevertheless, the position of the head restraint could be seen on the photos, which were made shortly after collision. But it could be assumed that some of the positions of the head restraints could have been changed during (insufficient fixation) or after the accident. Head restraints fixed in their lowest point of adjustment built the group of “low”, the ones fixed in their highest position defined the group “high”, everything in between formed “medium”.

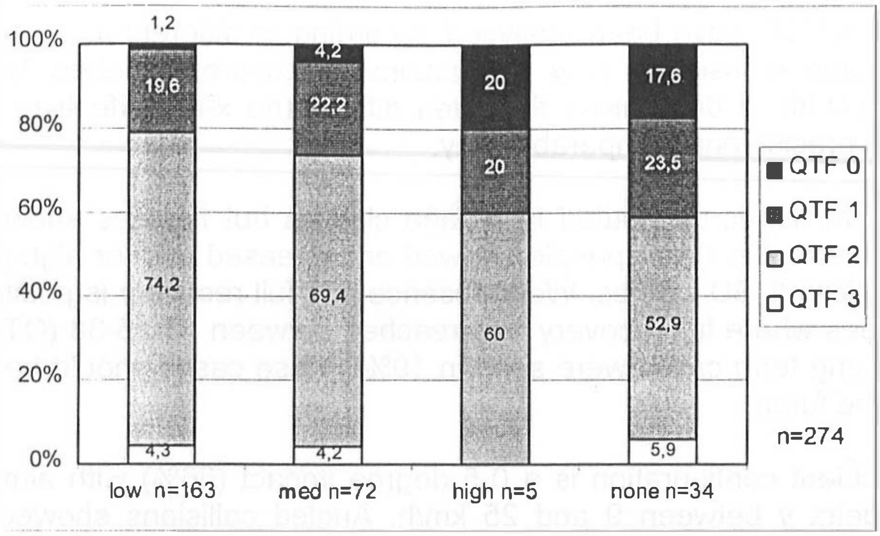


Figure 8: Head restraint adjustment and QTF degree

The distribution of the different QTF injuries among the groups 'low', 'medium' or 'high' head restraint position compared to 'no head restraint' shows a significant result: While in the group 'low head restraint' almost 74% suffer from QTF 2 injury and only 1.8% show no cervical spine symptoms, in the 'high positioned head restraint' collective the rate of QTF 2 is 60% and 20% show no cervical spine symptoms, although the case number with n = 5 is very small and does not allow a statistic interpretation.

In the 'no head restraint' group (which includes mostly passengers on the back seat), the situation is comparable to the 'high head restraint' results, but with a higher number of QTF 3 injured persons. Under this point of view it is obviously better to have no head restraint than having one with too low adjustment or, even worse, one low and not adjustable at all. However, a good (i.e. high) head restraint position can help to avoid a higher severity of cervical spine injury, when compared with low head restraint adjustment.

DISCUSSION

Although the incidence of CSD in Germany is statistically in a lower range than in other countries it plays a major role in traffic injuries. It is the second frequent injury claimed in car to car collisions and is constantly growing in number. About 50 % of all car to car accidents with injuries of the investigated retrospective insurance data material were rear end impacts, mostly associated with CSD injuries.
The advantage of this database is the full spectrum of insurance material which is representative for Germany and evenly distributed. On the other hand it is important to take into account possible insurance compensation expectancies of not liable rear-end accident victims. A not insignificant proportion of the data-sample, especially in the low (but also in the higher) delta v regions, could aggravate a pre-existing CSD disorder which would not be accident related. Moreover, there could be some subjective or also objective cervical spine symptoms because of degenerative changes or wrong therapy (neck collar). It was not the aim of this study to correlate CSD with biomechanical loading (delta v), therefore all (including the aggravated) injuries have been analysed for possible trends for a better medical objectivation of the injury.

In former studies CSD have been analysed according to different injury scales. The first attempt was made to use the new internationally accepted Quebec Task Force-CSD Staging (Grade 0-III). It determines the often diffuse (no x-ray effective) and subjective injury in a more precise and comparable way.

The population at risk is distributed in all age classes but females showed a 1.4 times higher injury occurrence. Older people showed an increased risk for high-graded (QTF III neurological deficits) CSD injuries. Work absence and full recovery is positively correlated with QTF degrees where full recovery was reached between 18-25-38 (QTF Grade I-II-III) days although long term cases were seen in 19%. These cases should be investigated in more detail in the future.

The typical accident configuration is a 0-5 degree impact (86%) with almost full overlap (50%) and a delta v between 9 and 25 km/h. Angled collisions showed no significant difference of the injury severity compared to non-angled collisions.

The QTF injury severity appears to decrease at higher delta v (26-50 km/h) ranges. This may be explained by an increased seat-back yielding or even seat back breakdown, which has to be further analysed in the future.

High head restraint adjustment seems to have strong positive effect in reducing QTF injury severity, whereas low head restraint adjustment worsens the injury outcome even in comparison to no head restraints. This might be explained by a higher hypomochlion (in the upper cervical spine) with head restraints positioned low in comparison to a hypomochlion located in the thoracic spine with a better injury tolerance. The same effect appears in the distribution of injuries compared with seating positions, where back seat passengers (often without head restraint) showed a significant better injury outcome (19% uninjured) in comparison to front seat passengers (only 3-7% uninjured). This stands in contrast to the findings from Minton et al. [20] who focuses on long-term disability and found no correlation between low-positioned head-restraints and disability frequence. Our results of a correlation between low-positioned head-restraints and the frequemcy of CSD injury at rear end collision were supported by the findings from Eichberger et al. [15], where the negative effect of a low positioned head-restraint have been demonstrated in sled tests as well as in injury statistics.

Although many medical and diagnostic problems are currently not solved it seems to be clear that an improved seat-head restraint design could prevent or at least reduce the number and severity of CSD injuries. Especially low weight cars have a strong need for an advanced seat construction because the occupants are exposed to a higher delta v, if hit by a heavier car. But also in midsize and large size cars the risk of a CSD injury could be reduced significantly if head restraints did not allow a low positioning (automatic positioning or integrated head restraint); in field investigations about 70% of all head-restraints were positioned low. Also rear seats should be fitted with adequate CSD protection.

OUTLOOK, NEW RESEARCH TOOLS AND RECOMMENDATIONS

The incidence of CSD in different countries should be analysed in terms of different economical (amount of compensation, insurance policy) and societal (long term cases more often in wealthy societies) questions. The very different occurrence of CSD can not be explained by different risk exposure only. So, the reasons for inadequate subjective and psychologically caused ailment must be found.

In medicine there is a need for an international standardisation for a better comparison of research results. New concepts for better objective diagnostics and advanced treatment concepts should be worked out. A planned prospective study about symptoms, collateral diagnoses, collision parameters and long term effects after rear end collisions seems to be necessary. Especially long term cases and QTF III cases have to be investigated in more detail.

In order to find adequate countermeasures against CSD research activities on the following topics are important:

- Low and medium delta v impacts (up to 25 km/h)
- Effect of higher delta v (> 25 km/h) on occupant movement
- Cinematic of back-seat car occupants
- Biomechanical background of CSD disorders
- New medical diagnostic methods for a better validation of CSD
- Definition and detailed analysis of long term cases
- Intelligent seat/ head restraint system concepts
- Better compatibility between cars with low and high mass (front/rear end)

ACKNOWLEDGEMENTS

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