

Characteristics of Neck Injuries of Car Occupants

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Abstract

Based on two independent accident studies of a 10 year research period with a total of 45,000 car accidents basic data on the occurrence of neck injuries are presented.

The risk determination of neck injuries by frequency and severity for front, side and rear end crashes is analysed.

The paper includes a review of literature and the results of neck injury occurrence are compared.

The distribution of neck injuries with seating position, sex, age and the correlation of neck injury and overall injury severity is discussed.

Results of the effect of head restraints and safety belts are presented.

1. INTRODUCTION

Neck injuries constitute one of the most prevalent traumas to car occupants in accidents. This type of injury shows two characteristic focal points: on the one hand, the extremely frequent minor injuries may cause long lasting pain but normally no permanent disability; on the other hand, severe neck injuries include the risk of possible damage to the cervical spinal cord and there does not seem to be a precise border with crash intensity, especially for unbelted occupants.

In view of these facts it is remarkable that only relatively few papers deal with neck injuries in real accidents.

This paper aims to present basic data on the occurrence of neck injuries in real accidents and their causation according to types of car impact. The results found from large scale material are compared with already existing results in order to come to a risk determination representative of car crashes in total. Factors influencing neck injury, such as seating position, sex and age of car occupants, are shown. The significance of neck injuries with regard to the overall injury severity of car occupants is discussed. Finally the paper outlines the efficiency of the safety systems head restraints and safety belts in reducing neck injuries.

2. BRIEF REVIEW OF EXISTING RESULTS REGARDING NECK INJURIES

The existing works may be classified into studies dealing with the classifications of neck injury kinematics and with the injury risk from medical or from technical engineering aspects. Results from some selected papers are discussed.

2.1 General classifications

General types of neck injury mechanism are shown in /1-3/. The neck injury occurrence is classified by type of force load /2/ or by direction of force /3/ to the neck (Table 1).

Some medical aspects of classifications of neck injury severity are discussed in /2,4,5,6,8/ dealing especially with problems of the diagnosis of neck injuries. Problems result mainly from the assessment of non-minor neck injuries without fractures or dislocations.

2.2 Some biomechanical results

Biomechanical analysis is rather difficult to carry out as human voluntary tests must be limited to non-injurious level and the results have to be translated to cadaver tests or medical analysis of segments of the cervical spine.

/7/ shows tolerance limits for the neck movement angle between head and upper dorsal spine segment which can be sustained without injury:

- anteflexion 60-70°
- retroflexion in a-p-direction 80-90°
- lateral flexion of neck 60-70°.

It was found /43/ that with integrated head restraints, supporting the head very closely, a 70 kph rear end impact without resulting in substantial injury may be sustained. The variation of g-load with varying distances of the head from the head support was found to be very significant. If no distance head/head support exists, a level of 10 g resulted from a 50 kph rear end impact; using a distance of more than 20 cm at the same crash intensity, a level of 80 g with a short maximum value of 230 g resulted. This clearly shows the biomechanical problems of neck injuries, as these are not only influenced by movement characteristics but also by the type of supporting or impacting surface and its relative distance.

2.3 Frequency of neck injury

Table 2 shows existing results on neck injury occurrence in real accidents /4,9-28/.

It is very remarkable that the percentages of neck injury frequency differ extremely from about 1 to 29% and that no generally valid ratio may be deduced. These differences of neck injury occurrence in the existing samples result from the fact that representative material must both include large numbers to show the risk of minor/moderate neck injuries adequately and, on the other hand, in-depth studies of critical/fatal neck injuries are necessary to cover these most important risks too; another difficulty results from the fact that neck injuries are highly correlated with the type of impact and therefore a "representative sample" also needs a "normalised distribution" of collision types.

Since till now almost all accident studies show a specific characteristic of accident sampling or of crash intensity, it is not yet possible to compare exactly the risk factors already existing for neck injuries.

2.4 Influence of type of impact

Most of the studies such as /17,18,20,28/ are directed to special types of impact, such as frontal collisions, rollovers etc.. Therefore, very few results exist regarding the distribution of neck injury occurrence versus type of impact. The predominant discussion of frontal and lateral impacts and rollover accidents shows that these types of impacts are regarded as causing most of the severe neck injuries, whereas neck injuries in rear end impacts are

reported to be mostly of minor/moderate degree only /29,44/.

2.5 Influences on neck injury occurrence

The influence of the seating position is discussed in different works. A slightly higher risk for the driver than for the right front passenger was found in /21,22,30/. Conversely, other works /15,18,28 and 31/ show an elevated risk for the right front passenger. A comparison also including the neck injury severity with driver and right front passenger could not be found. Whereas no uniform result exists regarding the front seat passenger, it is reported by several authors that rear seat occupants incur a far lower risk to neck injuries /4,15,30,31/.

Females were found to have a higher risk for neck injuries /30,31/; in /31/ it was found that this difference exists only for minor/moderate neck injuries, whereas the occurrence of serious and critical neck injuries is about balanced for males and females.

Surprisingly, no results regarding the distribution of neck injury frequency and age could be found, especially concerning older people. Children up to 10 years have a substantially reduced neck injury risk /32/, with increasing age and therefore greater height, the neck injury risk goes up and corresponds more and more to the values known from adults.

2.6 Effect of safety measures

All existing studies underline the importance of head restraints for reduction of neck injuries in rear end impacts. But only few results are available to quantify this reduction /7,30,31,44/. The level of neck injury reduction seems to be about 15% /30/ to 20% /31/.

/31/ shows that in rear end impacts without head restraints a disability to work for more than 3 weeks resulted in 25.8%, this share being reduced in identical car crashes with head restraints to only 16.6%.

In /37,38/ experimental cadaver tests showed the importance of the head restraints supporting the head about at its centre of gravity. Head restraints having a far lower positioning are not effective and lead only to another position of the neck injury at lower segments of the cervical spine. These papers also include comprehensive discussions of seat- and head restraint-characteristics.

A substantial reduction of serious/critical neck injuries was found with belted occupants /22,28,29,31,34,42,45,47,53/. On the other hand, the frequency of minor neck injuries with belted occupants is slightly higher /18,28,29,31,42,46,48,49,50-52/. It does not seem to be possible up to now to establish final reduction quotas of neck injuries AIS 3/6 by belt use as these neck injuries of belted occupants were found only in some single cases. But a reduction of at least 60% of the neck injuries AIS 3/6 by belt use seems to be reliable. It is reported in several works that serious neck injuries of belted occupants are to be found only in cases with head impact and no critical neck injuries were found by rotational movement only /25,28,33-36,42/.

3. THE ACCIDENT MATERIAL OF THIS REPORT

The aim of this paper - to present basic data on the characteristic occurrence of neck injuries in real accidents - was achieved by comparing results from

two large-scale accident studies.

- 28,936 car accidents with personal injury from the research period 1969 to 1974 (later on called "material 1") and
- 15,000 car accidents with personal injury from 1974 up to now (called "material 2").

Normally, the older research material 1 from 1969/74 is no longer used, as the car population has changed. But as neck injuries primarily depend on the type of impact in the car interior and not on the make of the car, it is permissible to use also material 1 for additional information. Both sets of accident material are based on unrestrained occupants.

As material 1 has about twice as many cases as material 2, it was possible to determine injury risks of 0.1%, which later on is shown to be the occurrence rate of critical neck injuries. With this result in mind, even large scale accident material should be handled with care in the significance of critical/fatal neck injuries; only a few cases included by chance in the material may change the percentage considerably.

Finally, an advantage of this comparison of two independent sets of material is the possibility to show long term trends of neck injury occurrence.

Both sets of material are analysed by the same evaluation procedure, described in /39,40/.

The accidents were evaluated by a team of HUK-engineers in conjunction with doctors in a retrospective multi-phase analysis; this enables the direct combination of large scale material with in-depth analysis included. The accidents included are mainly based on insurance cases in which at least one person suffered a minor injury AIS 1; in recent times more and more other independent basic material from direct police information and from cooperation with hospitals has been used.

Starting from the insurance files, the engineer team collects all data available on this accident which are established by any institution: the files include therefore existing police reports, in-depth medical reports on injury and rehabilitation, experts' reports on car damage, accident reconstructions etc.. These data are supported by photo documentation and interviews with the persons involved.

The overall injury severity and other injury data are known for all occupants involved. The detailed injuries to the various parts of the body - a comprehensive medical report being a pre-requisite for this - are known for every occupant in the "car not causing the accident". For the other party, the occupants' injuries are known from a medical report only in 60% of the cases.

This results from the basic "insurance cases" and from the protection of personal data by law. The detailed injury results are therefore mainly based on occupants of the "car not causing the accident" and this calls for a weighting procedure to arrive at a representative accident distribution (compare Table 5). The injury severity is coded, using the AIS classification /41/. Table 3 shows the distribution of occupant injury severity in both sets of material. The research material of this study covers frontal, side and rear end impacts in car-to-vehicle accidents; rollover cases, mostly resulting from single car accidents, are excluded as they show a different characteristic, which is analysed in a special report.

4. THE SIGNIFICANCE OF NECK INJURIES IN REAL ACCIDENTS

4.1 Occurrence by frequency

Table 4 shows the neck injuries included in both sets of material and their distribution by type of impact.

As the distribution of neck injury in Table 4 is based on the impact type distribution of the "party not causing the accident" - a weighting procedure is necessary to come to the total neck injury occurrence in a "normalised sample". Table 5 shows the distribution of types of impacts representative of the national statistics of car to car crashes. The normalised figures of "neck injury distribution" show that neck injuries are sustained by about 15-21% of the drivers and right front passengers related to the national car crash totals (rear seat occupants are excluded as these data are not available in the older material 1).

The significantly different average values of neck injuries in the older and the newer accident material cannot be explained. But - as shown later - this difference is mainly based on minor neck injuries AIS 1 and it might be possible that this type of injury - to which great attention is paid today - was regarded more as a secondary phenomenon about 10 years ago and, therefore, was not always noted in medical reports. A contributory factor might also be that the personal assessment of minor injuries has changed.

Table 5 shows that about one-third of all neck injuries (AIS 1 and above) result from frontal impact; side impacts cause about 27% and rear impacts about 40% of all neck injuries in non-rollover car crashes. It should be noted that these values are very sensitive to the distribution of "type of impact"

4.2 Resulting risk according to type of impact

4.2.1 Frontal impact (Table 6)

The differences of neck injury frequency between material 1 and material 2 is also reflected in frontal collisions. In material 2, which is to be regarded as significant for today, much higher percentages were found: 12.3 for the driver and 13.0 for the right front passenger.

The difference between material 1 and 2 covers mainly the minor category AIS 1, the distribution of the other injury categories AIS 3 to AIS 6 being almost identical.

In both sets of material the right front passenger incurs a slightly higher risk of neck injury, both for minor and for serious injuries. An outstanding result is the significantly reduced occurrence of neck injuries of rear seat passengers, with 5.7%.

4.2.2 Side impact (Table 7)

Again, the newer material 2 shows slightly higher frequency of neck injuries with 14.6% for drivers and 12.6% for right front seat passengers. This difference to material 1 results from minor injuries AIS 1.

The neck injury risk for drivers and right front passengers is about balanced, showing no uniform trend. This is to be explained by the fact that - unlike in frontal or rear end impacts - the injury risk in side collisions depends on the near-side or off-side seating position relative to impact.

This effect was analysed in material 2 (Table 8). The highest percentage of neck injury frequency in side collisions - 19.7% - results from the off-side driver, if no other passenger is in the car. In this case, the driver is

thrown laterally through the car and hits the right side interior of the compartment. This movement causes the high injury risk observed both by flexion and by direct force load. At high risk are also the impact side occupants, who show a neck injury risk of 10.1% or 15.4% respectively and comprised together with cross-thrown drivers all serious neck injuries registered in this sample.

The risk of the opposite side occupants is lower, with 7.6% or 14.6% respectively dominated by AIS 1 neck injuries. The total lack of serious injuries to off-side occupants should not be misunderstood. As the average risk of critical/fatal neck injuries is about 0.1 to 0.2%, it is influenced by chance, if accident material of about 500 opposite side passengers includes one or more serious injuries. This example shows that even in large-scale accident material the comparison of percentages should be handled with care and that mainly the trends of the existing risk distributions should be discussed.

Again, the substantial reduction of neck injury risk of rear seat passengers with 7.1% (table 7) was to be found. This result is very surprising, as the rear seat passenger in side collisions is influenced by the force load of impact/opposite side mechanism as well as the front seat passenger.

4.2.3 Rear-end impacts (Table 9)

Both independent sets of accident material show identical distribution of neck injury frequency and severity. Drivers incur an injury risk of about 51%, and right front seat passengers of 56%. Again, a significant reduction of neck injury frequency was to be found in rear seat occupants (18.5%). A major cause for this reduction might be that 29.7% of rear seat occupants are children of less than 10 years /39/; another 22.7% are children and younger adults from 10 to 19 years. This forms a total of 52.4% younger people on the rear seat, whereas this ratio on the right front passenger seat shows only 17%. Especially for children, the relative height of the seat back is so high that a full support of the head exists.

Both sets of accident material show that rear-end impacts mainly result in neck injuries AIS 1 and 2. Critical or even fatal injury risks are relatively low. From this it results that injuries of this high level must not necessarily occur in material 2.

An in-depth analysis of the neck injuries AIS 4/6 in material 1 showed that these injuries are mostly connected with a direct force load on the head/neck area when the occupant contacts the car's interior.

5. DISCUSSION OF INFLUENCING EFFECTS

5.1 Injury risk by seating position

As already discussed, the right seat passengers in the comparable front or rear end impact incur a slightly higher injury risk than the driver. This difference is mostly caused by minor and moderate injury severity with some indication from frontal impact that also for critical/fatal injuries the right front seat passenger seems to sustain a higher risk. A confirmation that this difference is not caused by chance, but seems to be based on a technical or a biomechanical cause, results from the totally different distribution in side collisions with their dominating effect of impact/opposite side mechanism.

A final explanation of this different risk of driver/right front passenger is not yet possible. Two factors may contribute:

- In frontal collisions even the unrestrained driver receives a certain restraining effect from the steering wheel/steering column. This may lead to a reduced direct force load on the head/neck area.
- About 70% of the drivers are male and 30% female, whereas right front seat passengers show a converse distribution with 23% males and 77% females /39/. As found already in /31/, females incur an elevated risk of neck injury AIS 1-2 compared with males and this may influence the discussed "different injury risk" by seating position.

Rear seat occupants show a significantly lower risk of neck injuries in any type of impact 2-3 fold lower compared with front seat occupants. This may be partly influenced by age and height distribution, but also a strong influence of injury mechanism seems to exist.

5.2 Characteristics of neck injuries in males and females

Special interest was directed to the question of whether a different risk distribution of males and females holds true also for the same seating position and for the same type of impact. Table 10 shows that females in general incur an elevated risk of neck injuries. As females are mostly passengers, it is often supposed that they show less counteraction to impact and this contributes to the higher risk. If this were true, no differences of neck injury risk regarding male or female drivers should be expected in frontal collisions. But according to Table 11 female drivers again show an elevated risk as compared to males. An effect of tension of the neck muscles counteracting the impact is therefore not to be found. This leads to the supposition that the elevated risk of neck injuries for females is correlated generally to the characteristics of the female neck muscles and ligaments.

Table 12 confirms this very clearly - both from the older material 1 and from the newer material 2. Almost the total difference of male/female neck injury risk is restricted to minor injury AIS 1 with some difference in AIS 2, too. Serious neck injuries of AIS 3 and above show exactly the same percentage, indicating that the risk of a neck fracture seems to be identical for males and females.

5.3 Influence of age

Medical studies of neck injury occurrence indicated that elderly people, due to their reduced biomechanical resistance, incur a higher risk of neck injury. Furthermore, the injury risk is elevated if a pre-damage of the neck exists already - this factor being higher with increasing age, too.

Table 13 shows the distribution of neck injury frequency and resultant severity. The basic age distribution is formed by reasons of data processing from "injured front seat occupants". Therefore, it should not be excluded that elderly people are injured more often and are thus overrepresented in this "basic age distribution".

It was expected that neck injury has a higher correlation to age than other injuries and that therefore - even on the basis of injured occupants - the occurrence of neck injuries should rise with increasing age.

But as shown in Table 13, this did not result, on the contrary, the age group of 50 years and above showed less neck injury frequency if injured in any body region than the age group 30 to 49 years, which represented the peak values of neck injury frequency.

Nevertheless, comparing the resultant neck injury severity, a slight increase of non-minor injuries was to be found with higher age. In conclusion it is to be stated that in this material the expected strong influence of age on neck injury occurrence could not be found, but it must be borne in mind that this table is based on injured front seat occupants only and includes all types of impacts and all categories of accident severity.

5.4 Neck injury severity versus overall injury severity

To get a feeling of the significance of neck injuries in total accident occurrence, the neck injuries according to frequency and severity are cross-tabulated against the overall injury severity.

Table 14 shows that out of a total of 860 cases with neck injuries in frontal impacts, 783 cases recorded the neck injury as the most severe injury to any body region. It should be borne in mind, however, that about 91% of these "dominating neck injuries" are of the AIS 1 level only. The critical OSI level AIS 4/5 is influenced by neck injuries in about 12%. The occurrence of fatal neck injury found in all fatalities in frontal impacts with 6.0% is too low. As only in about 20% of the fatalities an autopsy was made, it might be that corresponding fatal neck injuries are not reported. Experience of a study of 115 cases with autopsies in every type of car impact showed that neck injuries in about 10% cause fatalities of car occupants /32/.

In side impacts (Table 15) the numbers became relatively low and therefore they should not be regarded as reliable. The distributions observed, however, are indicated as they may offer a basis of comparison with other studies. In a sample of 2,262 cases with side impact, out of a total of 465 cases with neck injuries, 438 cases recorded the neck injury as the most severe injury, and this ratio is slightly higher than the comparative figure in frontal impact. Neck injury occurrence in side collisions should be analysed in more detail.

Totally different results are obtained in rear end impacts (Table 16). From 3,088 injured front occupants, 2,478 persons (80.2%) suffered their most severe injury to any body region from a neck injury. The risk in rear end collisions is greatly dominated by neck injuries. But it must be borne in mind that this is true only for the categories AIS 1-3; critical and fatal injuries in rear end collisions are mostly caused by injuries to other body regions.

5.5 Influence of safety systems

The results of this study, based on unrestrained occupants in cars - 20% of which are equipped with head restraints - should contribute to a realistic discussion of safety measures regarding the effect of belt and head restraints. From the risk quota observed here "expected values" of neck injury occurrence in accidents with belts and head restraints may be deduced.

The results of this study, showing the predominant occurrence of critical/fatal

neck injuries in front and side collisions, should not be misinterpreted so as to lower the importance of head restraints. It must be borne in mind that rear end impacts very often lead to a temporary and even sometimes a permanent disability.

AIS 1 neck injuries, too, for example minor whiplash injuries, are often reported to require a long process of recovery.

Against this background, results from /31/ gain in importance, according to which the risk of neck injuries is reduced by head restraints by about 20%. Difficulties in analysing the effect of head restraints in real accidents result from the fact that even when retroflexion is avoided a neck injury of minor degree might occur through the impact at the head restraint.

An adequate analysis of the effect of head restraint should include both the shifting effect of neck injury severity from a higher to a lower AIS category and the reduction of the duration of the inability to work. The result of this work showed that research of this kind is urgently required.

A significant effect on neck injury occurrence results from safety belts. By the restraining effect the direct force load on head/neck area is substantially reduced /42/ and this leads to an about two- or three-fold reduction of serious/fatal neck injuries. An exact figure cannot be presented at the moment as it is extremely difficult to establish two matched samples of equivalent crash intensity with and without belts with regard to critical neck injuries.

The restraining effect of belts in frontal collisions was found to increase the frequency of minor neck injuries at AIS 1 level by about 20% /31,42/. This slight overrepresentation of minor neck injuries is a small price to be paid for the decisive reduction of severe, critical and fatal neck injuries.

SUMMARY

Basic data on neck injury occurrence in real accidents are presented on the basis of 15,000 car crashes with personal injury from 1974 up to now, supplemented by additional material of 28,936 car crashes from the research period 1969/74. The comparison of this independent material proved to be very useful, as the rates of occurrence of critical/fatal neck injuries with their low percentages became more reliable and long-term trends of neck injury occurrence could be observed.

Neck injuries occur in about 20% of car crashes on average. The recent research material showed more minor neck injuries (about 5%) than the comparable sample 10 years ago. A partial explanation of this phenomenon might result from the special attention to neck injuries in the last few years and a different personal assessment of minor neck injuries today.

The discussion of the frequency and severity of neck injuries versus impact type and seating position is directed mainly to the occurrence of serious, critical and fatal neck injuries in representative accident material. Frontal and side collisions dominate regarding neck injuries AIS 3-6, whereas rear end collisions mostly cover minor/moderate neck injuries.

If in frontal or side collisions a neck injury occurs, this injury is at the same level as the overall injury severity in about 20% of the cases; neck injury and OSI 3-6 are at the same level in about 7% in front and side impact.

Of all rear end impacts about 80% are dominated in their lower injury categories by neck injuries; critical/fatal injuries mostly result from injuries other than neck injuries. In general, about 10% of all fatalities are caused by neck injuries.

In side collisions high risk exposure was found for the impact side passengers and especially for the opposite side driver alone and unrestrained in the car who is therefore subjected to a cross-throwing mechanism with serious impact of the side interior.

The right front passengers incur a slightly elevated risk as compared with the driver. The rear seat occupants show a significantly two- to three-fold lower risk as compared with front seat occupants.

The neck injury risk of females is increased compared with males and this holds true even for the same type of impact and seating position. This difference in neck injury risk is restricted only to a minor/moderate degree, more severe injuries of AIS 3 and above being identical for males and females. The increased risk of neck injuries seems to be correlated therefore with the characteristic of the female neck muscles and ligaments.

Younger people have a substantially reduced risk of neck injury frequency. Related to injured front occupants, the frequency of neck injuries was found to be about balanced from the age of 30 years and above; no strong indication of substantially increased neck injury frequency in older people could be found. But with increasing age, the resultant injury severity showed a slight increase of non-minor injuries.

The reduction of neck injuries by head restraints is assessed at about 20%; this value may be regarded as a lower limit.

The most significant effect in reducing critical/fatal neck injuries can be achieved by safety belts, as these serious neck injuries at least in half of the cases occur in frontal collisions and are dominantly caused by direct force load on the head/neck areas.

A reduction of at least 60% of these critical/fatal neck injuries in frontal collisions by belt-use seems reliable. Research in this field is urgently required; the results of this report aim to contribute to a realistic assessment of neck injury risks and possible safety measures.

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TYPE OF FORCE LOAD		
EXTENSION - TENSION	FLEXION - COMPRESSION	EXTENSION - COMPRESSION

Table 1. Typical Injury Mechanisms /3/

AUTHOR	YEAR	FREQUENCY OF NECK INJURIES	TYPE OF ACCIDENT	REMARKS
Kulowski /11/	1956	28,6%, related to number of injured occupants	-	hospitalized persons only
Braunstein /10/	1957	6,8%, related to number of injured occupants	-	-
Kultus- ministerium Nordrhein/ Westfalen /9/	1959	driver: 7%, right front: 9%, rear: 9% 8,1%, related to number of injured occupants	all kinds of car accidents	500 car accidents 848 injured occupants
VOLVO /22/	1965/66	driver: 19%, right front: 18%	all kinds of car accidents	28.780 car accidents 37.511 injured occupants
Nahum /26/	1966	2 %	-	-
Mackay /13/	1967	driver: 1,8%, right front: 0,7%	all kinds of car accidents	425 car accidents
States /4/	1968	front seat occupants: 5,6%, rear: 1,4%	car side impact	74 occupants in side- impacted cars
Krieg /23/	1968	with seat belt: 13,8%, without seat belt: 16,3%	-	-
Gögler /14/	1970	7,9 %	-	3079 car occupants
Nahum /27/	1970	2,4 %	all kinds of car accidents	604 cars, 972 occupants
O'Neill /24/	1971	driver, with head restraint: 24%, without headrestraint: 29%	rear end impact	67.000 cases 5.663 rear end impacts
Hight /17/	1972	with seat belt: 7%, without seat belt: 13%	rollover	139 rollover cases 225 occupants
Gögler /12/	1972	5%, related to 325 occupants AIS = 6	-	3079 car accidents
Grattan /16/	1973	3,5 %	-	car accidents with 172 occupants AIS = 6
Grattan /15/	1974	driver: 2,4%, right front: 3,4%, rear: 1,8%	all kinds of car accidents	879 injured occupants
Hartemann /20/	1976	7,9 %	car side impact	419 injured occupants
Bourret /18/	1977	4,8 %	frontal impact	606 injured occupants
Hartemann /21/	1977	driver: 1,2%, right front: 0,5%	frontal impact	200 car front seat occupants, AIS \geq 2
Walz /25/	1977	9,3 %	all kinds of car accidents	410 injured occupants with seat belt
Huelke /28/	1977	with seat belt: 26,5%,* " " " 20,3% * without seat belt: 13,6% " " " 18,0%	frontal impact rollover frontal impact rollover	4165 front seat occupants *without severe/fatal injuries
Shanks /19/	1979	5,1%	all kinds of car accidents	74 accidents, 84 injured occupants, AIS \geq 2

Table 2. Frequency of Neck Injury Occurrence - Review of selected Publications from Real-Life Accident Analysis

SEVERITY OF INJURY (AIS)	HUK RESEARCH MATERIAL 1 1969/74				HUK RESEARCH MATERIAL 2 1974 AND UP			
	28,936 ACCIDENTS				15,000 ACCIDENTS			
	50,464 CAR OCCUPANTS = 100 %				19,387 CAR OCCUPANTS = 100 %			
	OVERALL INJURY SEVERITY		SEVERITY OF NECK INJURY		OVERALL INJURY SEVERITY		SEVERITY OF NECK INJURY	
	NUMBER	%	NUMBER	%	NUMBER	%	NUMBER	%
0 (UNINJURED)	10,584	21,0	41,559	82,3	4,507	23,2	12,257	73,6
1 (MINOR)	30,481	60,5	8,066	16,0	11,992	61,9	4,007	24,1
2 (MODERATE)	6,827	13,5	672	1,3	2,016	10,4	338	2,0
3 (SEVERE)	1,540	3,1	86	0,2	515	2,6	15	0,1
4/5 (CRITICAL)	383	0,8	32	0,1	130	0,7	13	0,1
6 (FATAL)	566	1,1	49	0,1	227	1,2	9	0,1

Table 3. Accident Material of this Report. Distribution of Overall Injury Severity and of the Neck Injuries recorded in both Samples

TYPE OF IMPACT	MATERIAL 1				MATERIAL 2			
	DISTRIBUTION OF TYPE OF IMPACT	CARS INVOLVED	FRONT OCCUPANTS	FRONT OCCUPANTS WITH NECK INJURY	DISTRIBUTION OF TYPE OF IMPACT	CARS INVOLVED	FRONT OCCUPANTS	FRONT OCCUPANTS WITH NECK INJURY
FRONT	45,8%	13,107	20,197	1,436	45,1%	4,779	6,878	798
SIDE	28,0%	8,015	12,150	1,244	22,1%	2,342	3,314	487
REAR	26,2%	7,515	11,102	5,836	32,8%	3,476	4,800	2,913
TOTAL	100%	28,637	43,449	8,516	100%	10,597	14,992	4,198

Table 4: Distribution of Types of Impact versus Occupants involved

TYPE OF IMPACT	REPRESENTATIVE DISTRIBUTION [39]	MATERIAL 1			MATERIAL 2		
		NORMALIZED DISTRIBUTION OF FRONT OCCUPANTS	FRONT OCCUPANTS WITH NECK INJURY NUMBER	%	NORMALIZED DISTRIBUTION OF FRONT OCCUPANTS	FRONT OCCUPANTS WITH NECK INJURY NUMBER	%
FRONT	58, 1%	25,621	1,822	29, 1	8,860	1,028	32, 5
SIDE	27, 4%	11,890	1,217	19, 4	4,109	849	26, 8
REAR	14, 5%	6,144	3,230	51, 5	2,122	1,288	40, 7
TOTAL	100%	43,655	6,269	100	15,091	3,165	100

AVERAGE RISK OF NECK INJURY OCCURRENCE

14, 4%

21, 0%

Table 5. Normalized Distribution of Neck Injury Occurrence according to a Distribution of Impact Types representative of Car Accidents

FRONT IMPACT - MATERIAL 1							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	13,107 100 %	795 6,07 %	76 0,58 %	10 0,08 %	2 0,12 %	14	897 6,80 %
FRONT SEAT PASSENGER	7,090 100 %	463 6,53 %	52 0,73 %	9 0,13 %	6 0,21 %	9	539 7,60 %

FRONT IMPACT - MATERIAL 2							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	4,779 100 %	537 11,24 %	43 0,90 %	3 0,06 %	2 0,08 %	2	587 12,30 %
FRONT SEAT PASSENGER	2,099 100 %	238 11,34 %	27 1,29 %	1 0,05 %	5 0,33 %	2	273 13,00 %
REAR SEAT PASSENGER	743 100 %	38 5,11 %	3 0,40 %	1 0,13 %	-	-	42 5,70 %

Table 6. Neck Injury Occurrence in Front Impacts versus Seating Position

SIDE IMPACT - MATERIAL 1							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	8.015 100 %	743 9,27 %	63 0,79 %	17 0,21 %	3 0,11 %	6	832 10,40 %
FRONT SEAT PASSENGER	4.135 100 %	361 8,73 %	39 0,94 %	3 0,07 %	3 0,22 %	6	412 10,00 %

SIDE IMPACT - MATERIAL 2							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	2.342 100 %	315 13,45 %	25 1,07 %	1 0,04 %	1 0,08 %	1	343 14,60 %
FRONT SEAT PASSENGER	972 100 %	111 11,42 %	10 1,03 %	-	-	1 0,10 %	122 12,6 %
REAR SEAT PASSENGER	364 100 %	23 6,32 %	3 0,82 %	-	-	-	26 7,10 %

Table 7. Neck Injury Occurrence in Side Impacts versus Seating Position

LEFT SIDE IMPACT - MATERIAL 2							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
I. S. - DRIVER	1,515 100 %	215	17	-	1	1	234 15,40 %
O. S. - FRONT SEAT PASSENGER	526 100 %	70	7	-	-	-	77 14,60 %

O. S. = OPPOSITE SIDE } POSITION OF CAR OCCUPANT RELATED TO IMPACT
I. S. = IMPACT SIDE }

RIGHT SIDE IMPACT - MATERIAL 2							
SEATING POSITION	(OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
WITH FRONT SEAT PASSENGER	446 100 %	33	1	-	-	-	34 7,60 %
O. S. - DRIVER	381 100 %	67	7	1	-	-	75 19,70 %
WITHOUT FRONT SEAT PASSENGER	446 100 %	41	3	-	-	-	45 10,10 %

Table 8. The Influence of Impact/Opposite Side Position of Occupants in Side Impacts

REAR END IMPACT - MATERIAL 1							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	7,515 100 %	3,538 47,08 %	282 3,75 %	27 0,36 %	12 0,17 %	1	3,860 51,40 %
FRONT SEAT PASSENGER	3,587 100 %	1,824 50,85 %	136 3,79 %	12 0,33 %	2 0,11 %	2	1,976 55,10 %

REAR END IMPACT - MATERIAL 2							
SEATING POSITION	TOTAL (OSI 0-6)	SEVERITY OF NECK INJURY (AIS)					NECK INJURY TOTAL
		1	2	3	4/5	6	
DRIVER	3,476 100 %	1,642 47,24 %	137 3,94 %	1 0,03 %	- -	-	1,780 51,20 %
FRONT SEAT PASSENGER	1,324 100 %	692 52,27 %	49 3,70 %	2 0,15 %	- -	-	743 56,10 %
REAR SEAT PASSENGER	540 100 %	91 16,85 %	9 1,67 %	- -	- -	-	100 12,50 %

Table 9. Neck Injury Occurrence in Rear End Impacts versus Seating Position

MATERIAL 2					
TYPE OF IMPACT	INJURED FRONT SEAT OCCUPANTS TOTAL (OSI 1-6)	SEX	INJURED FRONT SEAT OCCUPANTS (OSI 1-6)	NECK INJURY	
				NUMBER	%
FRONT	5,133	MALE	2,885 100	431	14,9
		FEMALE	2,248 100	429	19,1
SIDE	1,372	MALE	832 100	138	16,6
		FEMALE	540 100	141	26,1
	890	MALE	405 100	76	18,8
		FEMALE	485 100	110	22,7
REAR	3,088	MALE	1,486 100	1,171	78,8
		FEMALE	1,602 100	1,352	84,4

Table 10. Neck Injury Frequency of Males and Females in different Types of Car Impacts

MATERIAL 2					
TYPE OF IMPACT	INJURED DRIVERS TOTAL (OSI 1-6)	SEX	INJURED DRIVERS (OSI 1-6)	NECK INJURY	
				NUMBER	%
FRONT	3,351	MALE	2,441	379	15,5
		FEMALE	910	208	22,9
REAR	2,149	MALE	1,346	1,078	80,1
		FEMALE	803	702	87,4

Table 11. Neck Injury Frequency of Male/Female Drivers in Front and Rear End Impacts

MATERIAL 1							
INJURED FRONT SEAT OCCUPANTS TOTAL (OSI 1-6)	SEX	INJURED FRONT SEAT OCCUPANTS (OSI 1-6)	SEVERITY OF NECK INJURY (AIS)			NECK INJURY	
			1	2	≥ 3	NUMBER	%
35.845	MALE	21.403	4.068	340	95	4.503	21,0
		100	19,0	1,6	0,4		
	FEMALE	14.442	3.692	309	60	4.061	28,1
		100	25,6	2,1	0,4		

MATERIAL 2							
INJURED FRONT SEAT OCCUPANTS TOTAL (OSI 1-6)	SEX	INJURED FRONT SEAT OCCUPANTS (OSI 1-6)	SEVERITY OF NECK INJURY (AIS)			NECK INJURY	
			1	2	≥ 3	NUMBER	%
10.483	MALE	5.608	1.665	141	10	1.816	32,4
		100	29,7	2,5	0,2		
	FEMALE	4.875	1.870	150	12	2.032	41,7
		100	38,4	3,1	0,2		

Table 12. Distribution of Neck Injury of Males and Females

MATERIAL 2						
AGE	INJURED FRONT SEAT OCCUPANTS	NECK INJURY	SEVERITY OF NECK INJURY (AIS)			
	TOTAL (OSI 1-6)	TOTAL	1	2	3	4 - 6
10 - 19	100 814	16,8 137 100	126 92,0	10 13,7	1 1,3	-
20 - 29	100 3.385	30,0 1.010 100	940 93,1	60 5,9	4 0,4	6 0,6
30 - 39	100 2.730	35,8 978 100	903 92,3	71 7,3	1 0,1	3 0,3
40 - 49	100 1.584	34,8 552 100	496 89,8	53 9,6	1 0,2	2 0,4
≥ 50	100 1.789	30,8 552 100	485 87,9	63 11,4	1 0,2	3 0,5

Table 13. Frequency and Resulting Severity of Neck Injuries versus different Age Groups

FRONT IMPACT - MATERIAL 2							
OVERALL INJURY SEVERITY (OSI)	INJURED FRONT SEAT OCCUPANTS TOTAL	NECK INJURY TOTAL	SEVERITY OF NECK INJURY (AIS)				
			1	2	3	4/5	6
1	3,810 100	702	702 18,4	-	-	-	-
2	937 100	122	-	66 7,0	-	-	-
3	258 100	20	14	2	4 1,6	-	-
4/5	61 100	11	3	1	-	7 11,5	-
6	67 100	5	-	1	-	-	4 6,0
TOTAL	5,133	860	CASES WITH NECK INJURY AT SAME LEVEL AS OVERALL INJURY: 783				

Table 14. Distribution of Neck Injury Severity in Front Impact versus highest Injury Severity to any Body Area

SIDE IMPACT - MATERIAL 2							
OVERALL INJURY SEVERITY (OSI)	INJURED FRONT SEAT OCCUPANTS TOTAL	NECK INJURY TOTAL	SEVERITY OF NECK INJURY (AIS)				
			1	2	3	4/5	6
1	1,840 100	400	400 21,7	-	-	-	-
2	298 100	57	23	34 11,4	-	-	-
3	89 100	5	3	1	1 1,1	-	-
4/5	19 100	1	-	-	-	1 5,3	-
6	16 100	2	-	-	-	-	2 12,5
TOTAL	2,262	465	CASES WITH NECK INJURY AT SAME LEVEL AS OVERALL INJURY: 438				

Table 15. Distribution of Neck Injury Severity in Side Impact versus highest Injury Severity to any Body Area

REAR END IMPACT - MATERIAL 2							
OVERALL INJURY SEVERITY (OSI)	INJURED FRONT SEAT OCCUPANTS TOTAL	NECK INJURY TOTAL	SEVERITY OF NECK INJURY (AIS)				
			1	2	3	4/5	6
1	2,791 100	2,293	2,291 82,1	2	-	-	-
2	277 100	221	37	184 66,4	-	-	-
3	13 100	6	3	-	3 23,1	-	-
4/5	6 100	3	3	-	-	-	-
6	1 100	-	-	-	-	-	-
TOTAL	3,088	2,523	CASES WITH NECK INJURY AT SAME LEVEL AS OVERALL INJURY: 2,478				

Table 16. Distribution of Neck Injury Severity in Rear End Impact versus highest Injury Severity to any Body Area