BELTED OCCUPANTS IN OBLIQUE AND SIDE IMPACTS

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ABSTRACT

On January 1,1976 a law became effective in Switzerland requiring passenger car occupants to be secured by safety belts.At the same time the Swiss Government initiated a one year study on car accidents involving persons who were belted and sustained severe or fatal injuries. 304 accidents with 153 killed and 257 severely injured (OAIS = 2-6) occupants were analysed during this study. Data collection and analysis are based on police reports,hospital documentation, photographs and in part on scene investigations,photogrammetric methods and technical examination of the belts.

Frontal crashes with an impact direction of 12 o'clock are the most traumatic ones for belt wearers.Nearly the same traumatisation arises from oblique collisions with 1,2,10 and 11 o'clock impact direction. The latter are analysed in terms of seating position,injury pattern and severity. The same relations are shown also for the 3 and 9 o'clock side impacts.

This paper has to be viewed in connection with other papers published by the same authors.

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I. INTRODUCTION

The injury reducing potential of correctly worn seat belts has been proven to date in numerous studies (Scott(1),Huelke(2),Langwieder (3),Daalgard(4),Voigt(5),Walz(6),Bohlin(7),Petty(8),Nordentoft(9), Sabey(1o),Herbert(11),Mackay(12),Kahane(13),Henderson(14),Cameron (15)).This fact justified the introduction of a mandatory seat belt law in Switzerland,effective January 1,1976. As a consequence , usage rates in relation to the cars equipped with belts (91% in 1976) increased from aproximately 15%,35% and 4o% in previous years to 77%,85% and 92% in city,rural and expressway driving,respectively BfU(17). The problems of car occupant protection,however,cannot be expected to be solved exhaustively with a mandatory seat belt law,and,in addition,even new questions might emerge.For these reasons,the Swiss Federal Police Department initiated a one year study on severely and fatally injured seat belt users.The investigations should reveal to what extent safety belts itself are the cause of injuries and under which crash conditions they are incapable of preventing injuries.

The relevant documentation obtained consisted usually of police reports,photographs and scaled sketches of the accident scene based on photogrammetric evaluation.Furthermore,the treating doctors and coroners contributed hospital reports and autopsy documantation in addition to personal communications.The investigating team made an effort to inspect the involved vehicles in the neighborhood of Zurich.In the other cases,personal contact between the investigator and the police officer provided the additional information.

In a number of cases the belts were taken from the car for further investigations.These were performed by the Swiss Federal Materials Testing Laboratory and the Technical College of the Canton Berne at Biel.

A total of 3o4 accidents involving 336 cars and light vans as well as 41o belted persons with an injury severity of OAIS 2-6+ were investigated.153 of these occupants died.

This paper has to be viewed in connection with other papers concerning this one year study (Niederer(18),Walz(19),Walz(2o),Walz(21), Niederer(22)).

II. Results

II.1. OBLIQUE IMPACTS

The 141 proper frontal impacts (12 o'clock) implied a degree of traumatisation (=d.o.tr.) = Σ ISS of 3582,an average ISS of 25,4 and 45 fatalities (Tab.1). The 117 oblique impacts with 1,2,1o and 11 o'clock impact direction follow with a d.o.tr.of 3o27,an average ISS of 25,8 and a fatality rate of 44.The 72 persons sitting at the side of the impact area sustained more severe injuries (av.ISS= 28,6 and 34 fatalities) than the remote occupants (av.ISS= 21,4 and 1o fatalities).The difference ,however,is not significant due to the relatively small number of cases (Tab. 2).
The overall traumatisation of the people sitting close to the crush zone is more than the double compared to the opposite occupants (Σ ISS =2o62 vs.965).The nearside occupants sustained weakly significantly more leg injuries ($p \leq o,1$)and arm injuries ($p \leq o,1$) and they had a higher death rate ($p \leq o,1$).The more frequent incidence of pelvic fractures is significant($P \leq o,o5$).

In contrast to that the persons sitting opposite to the impacted area were affected weakly significantly more often by AIS 2 rated head injuries ($p \leq o,1$) and fractures of the lumbar spine ($p \leq o,1$).The difference in terms of lacerations to the bowel is significant ($p \leq o,o25$) and regarding brain contusions even highly significant($p \leq o,ool$).

Whereas the high frequence of pelvic,leg,and armінjuries with the directly impacted occupants is easily explained by the car crush near the person under consideration, the higher incidence of head injuries to the o f f s i d e occupants is surprising.Taking into account the likewise more frequent affections of the bowel and the lumber spine,the following interpretation is possible: the offside occupant glides out of the shoulder belt towards the impact area and thereby contacts - as passenger in 1o and 11 o'clock crashes - the steering wheel rim with his head ,the upper dashboard,the gear shift lever or even the other occupant.The directly impacted occupant contacts in contrast to that often

Collision circumstances	Number of cases	ΣISS	average ISS	Number of fatalities
12 o'clock	141	3582	25,4	45
11 "	59	1470	24,9	18
10 "	16	503	31,4	8
1 "	24	604	25,1	10
2 "	18	450	25,0	8
3 "	26	820	31,5	12
9 "	23	506	22,0	8
4-8 "	10	188	18,8	3
Rollover	19	517	27,2	10
Complex	24	1924	26,0	31
Total	410	10564	25,8	153
Included are				
Ejection	15	672	44,8	9
Fall	19	448	23,6	4
Water	3	57	19,0	3
Fire	8	64	8,0	-
Underrun	27	1085	40,2	18

Tab 1 : Distribution of collision circumstances and degrees of traumatisation (=Σ ISS) in the sample.

	1,2,1o,11 o'clock impact direction			3 and 9 o'clock impact direction		
	near-	offside	Signif.of near/off-side difference	near-	offside	Signif.of near/off-side difference
n	72	45		33	16	
ISS	2o62	965		991	335	
Ø ISS	28,6	21,4	n.s.	3o,0	2o,9	n.s.
Stand.error	3,4	3,2		5,2	5,2	
n of deaths	34	1o	***	17	3	*
Cerebr.conc.	17	24	****	7	5	n.s.
cerebr.cont.	17	7	n.s.	6	4	n.s.
Skull fract. (vault)	1o	4	n.s.	4	2	n.s.
(base)	15	3	n.s.	8	1	n.s.
Facial fract.	15	11	n.s.	6	4	n.s.
Eye injury	3	2	n.s.	-	-	
Persons with head injuries	45	34	*	1o	1o	***
Cervic.spine	4	5	n.s.	2	2	n.s.
Thoracic sp.	3	-		-	-	
Lumbar spine	2	4	*	1	-	
Spinal cord	-	1		1	2	
Clavicle fr.	3	2	n.s.	5	2	n.s.
Sternum frac.	3	2	n.s.	2	-	
Rib fracture	23	14	n.s.	22	7	n.s.
Heart	4	3	n.s.	2	1	
Lung	7	1	n.s.	7	2	n.s.
Aorta	5	1	n.s.	1	-	
Pers.with thorac.inj.	28	17	n.s.	26	1o	n.s.
Liver	12	3	n.s.	4	2	n.s.
Spleen	1o	2	n.s.	5	-	
Kidney	4	4	n.s.	3	2	n.s.
Bowel	1	4	***	2	-	
Unspecific abdom.injury	1o	7	n.s.	3	2	n.s.
Pers.with abdom.inj.	2o	12	n.s.	8	5	n.s.
Pelvic fract.	18	2	**	15	2	*
Leg fracture	37	14	*	5	2	n.s.
Arm fracture	23	5	*	7	-	

Tab. 2 : Injuries and traumatisation in oblique and side impacts.

only the side window and therefore he sustaines headinjuries of AIS ≤ 1.

The head impact velocity is expected to be higher with the r e m o t e sitting occupant because of the longer distance available for the acceleration. It must also be born in mind that this sample includes a relatively large number of very severe collisions with a VDI extent of 5 and more (45% of all 1, 2,1o and 11 o'clock impacts) so that the head can contact the intruding car structures on the opposite side,especially the roof.

Photo No.1 : Roof contact of the offside occupant with fatal head and neck injury.

During the sideways movement the load on the lap strap rises and bowel lacerations thereby occur. The rotation around the lower part of the shoulder strap is hypothesized to be the reason for the particular lumbar spine fracture. In two of the four fractures tearing of the transverse processes occurred on the left side of 11 o'clock impacted right side sitting passengers.Non of the other 4o8 severely injured belt wearers showed this particular spine fracture.
Wide cars,molded steering wheel rims (also for the sake of the passengers) and other softened structures of the car interior (e.g.gear shift lever,driving mirror) are regarded as feasible improvements .Preventing the gliding out of the shash belt would riquire more expensive (air bag) or impractical (four point racing belt) safety measures.

Of the 117 persons involved in 1,2,1o an 11o'clock crashes 72 were accompanied by an other belted front occupant (Tab.3).47 times (= 65%) the occupant sitting close to the crush zone was more severely injured than the other but in 24% of the cases the i n v e r s e situation occurred (Photo No.2). In the remaining 8 cases (=11%) both occupants exhibited the same injury severity in terms of OAIS and ISS.In two cars both front occupants with belts were killed in oblique impacts (four persons).Old age was found to be one of the major reasons contributing to the severe injuries of offside sitting occupants(Walz et al.21).

	Nearside occupant more severely injured	Offside occupant more severely injured	Same injury-severity	Only one occupant in the car	Other occupant not belted
1,2,1o,11 o'cl. impact direction	47 = 65%	17 = 24%	8 = 11% (1oo%)	41	4
3 and 9 o'clock impact direction	21 (= 81%)	1 (= 4%)	4 (= 15%) (1oo%)	18	5

Tab. 3 : Injury severity with respect to seating position in oblique and side collisions.

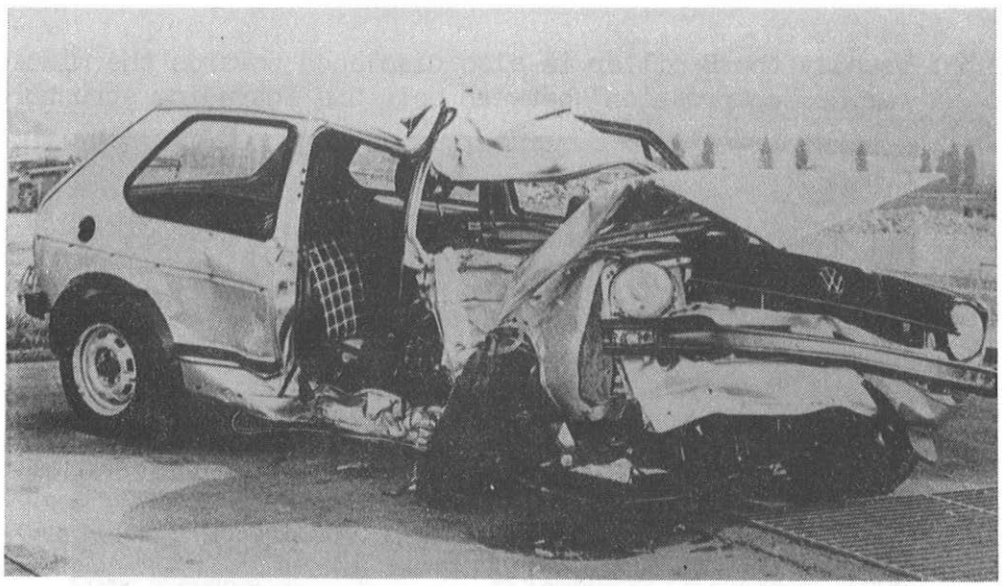

Photo No. 2 : Driver (offside) killed, nearside passenger injured OAIS 3,ISS 13.

II. ii. SIDE IMPACTS

Doubts about seat belt effectiveness in side impacts are unjustified in view of present results (Walz(6),Jones(16),Hartemann(17)).This study revealed that compression of the occupant between the belt and the intruding side structure usually does not occur because the B-pillar and the side belt anchors attached to it is also displaced towards the middle of the car so that the available length of the belt remains sufficient (photo No.3 and 4). The av. Δv in side impacts is considerably lower(35 km/h) than in frontal crashes (5o km/h).Due to the impossibility to provide an adequate deformation zone as in the frontal direction the intrusions resulting from side impacts are increased allready with low v.

Photo No. 3 : Usually the B-pillar is also displaced towards the middle of the car.No "compression" between belt and intruding structure occurs.

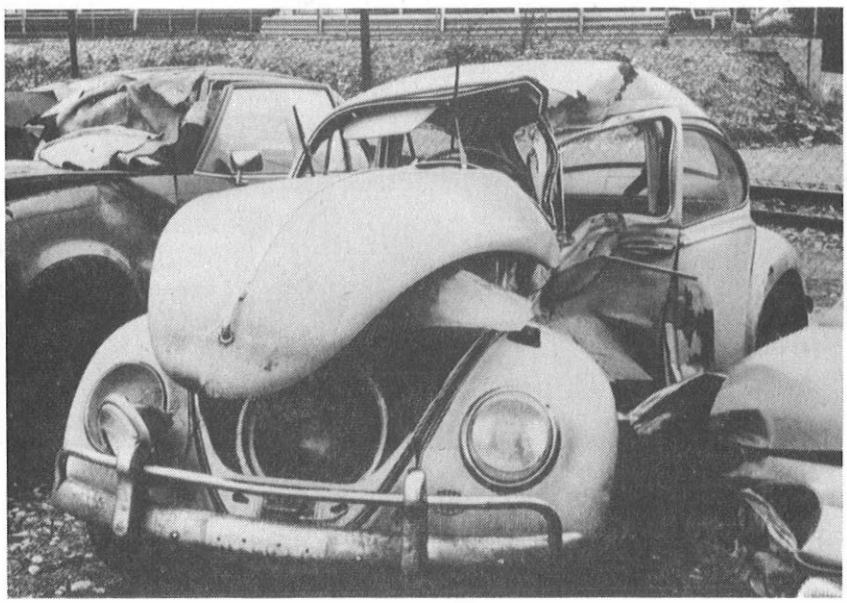

Photo No. 4 :Rarely ,the B-pillar is n o t displaced.

The overall traumatisation of the belted persons directly struck is three times as high as the one of the other belted occupants in side crashes (d.o.tr. of 991 vs. 335).The higher incidence of pelvic and arm injury rated AIS ≥ 2 for the nearside occupant is weakly significant (p ≤ o,1) and death occurred more often (p ≤ o,1) .The offside occupants sustained significantly more AIS ≥ 2 head injuries than the others (lo among 16 vs. lo among 33 , p ≤ o,o25).

As the statistical evaluation of the injury pattern with the nearside resp. the offside occupants shows similar results as in the case of oblique crashes it is assumed that the same interpretation of the injury causation is valuable.

26 of the 49 severely injured belt wearers involved in side collisions were togeather with an other belted front seat occupant (Tab. 3). 21 (= 81%) sustained more severe injuries while sitting close to the impacted side than the offside person.

In two accidents the nearside as well as the offside occupants were injured with the same degree of severity (4 cases,OAIS 6+). An example is shown in photo No. 5.

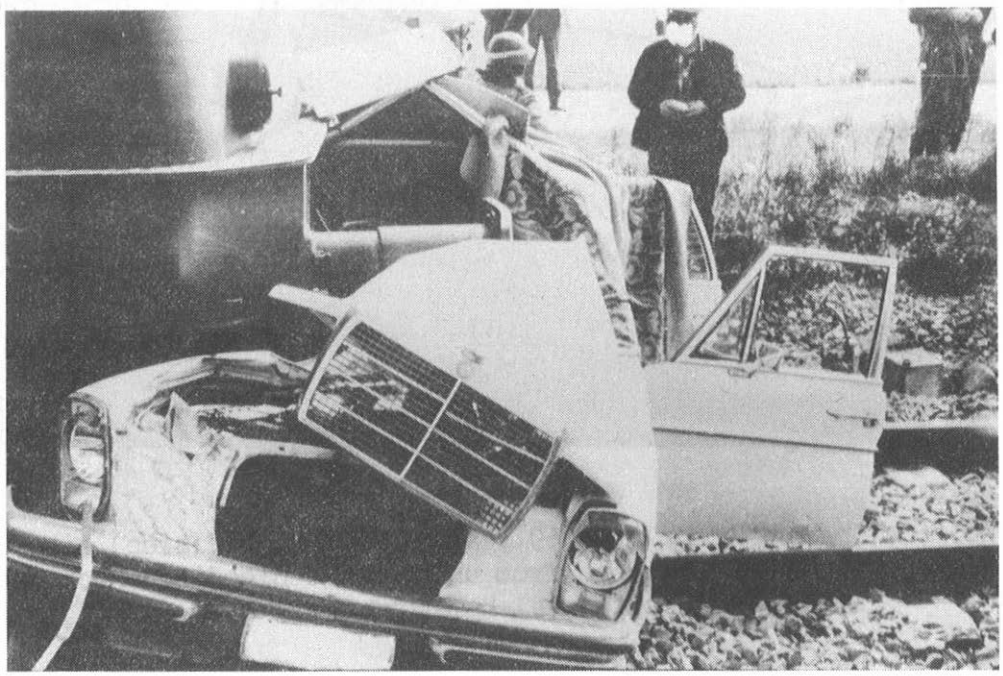

Photo No. 5 : Both belted front seat occupants were killed in this side collision with a train.

In one case the offside driver (69 years old,anticoagulated) died two days after a minor right side impact from a retroperitoneal hematoma and bleeding shock (photo No . 6).Because of the absence of visible lesions and pain the patient was not kept in the hospital after the first check up; the following day he was admitted to the hospital again but the bleeding shock could not be treated any more due to the occult anticoagulation bleeding. The injuries were caused -with a high degree of probability - by the buckle of the two point diagonal belt; the 61 year old nearside sitting woman suffered from AIS 3 rated rib fractures with hemathorax and a contusion of the right shoulder.She had to stay 21 days in the hospital. The conclusion can be drawn that a healthy driver in offside position would have sustained only minor injuries in this accident.

Photo No. 6 : The anticoagulated 69 year old driver (offside) died two days after the accident from untreatable bleeding shock.No visible injury,retroperitoneal hematoma.

SUMMARY

The results of a one year study initiated by the Swiss government involving accident circumstances of 257 injured (OAIS 2-6) and 153 killed (OAIS 6+) seat belt wearers are presented with respect to 117 oblique and 49 side collisions. Oblique impacts(1,2,10,11 o'clock) represent approximately the same overall hazard to belted occupants as the 12 o'clock frontal impacts (degree of traumatisation = Σ ISS : 3027 vs.3582,fatality rate 44 vs.45).In general occupants near the impact sustained more often and more severe injuries (esp. leg,arm and pelvic fractures). However, the offside occupants sustained more often head,bowel and lumbar spine injuries. As reasons for these findings a higher head impact velocity due to the longer acceleration distance ,contact with the steering wheel by the passenger , rotation around the sash portion of the belt with partial gliding out of it are stipulated.On the other hand the nearside occupant sustaines often only minor head injuries due to a relatively "smoth" impact to the side window. These reasons and older age contributed to the fact that in 24% the offside occupants involved in oblique crashes suffered from more severe injuries than their directly impacted couterparts.

In 3 and 9 o'clock side collisions the persons opposite to the crush zone sustained as in the oblique crashes significantly more frequent head injuries whereas the incidence of arm and pelvic fractures is higher with the occupants close to the impact.The latter also exhibited highly significantly more thorax and pelvic injuries AIS $\geq$ 2) than occupants in all other collision circumstances.

References

(1) SCOTT R.E., Flora J.D., Marsh J.C.:An Evaluation of the 1974 and 1975 Restraint Systems. UM-HSRI-76-13, 1976. Highway Safety Research Institute, University of Michigan

(2) HUELKE D.F.: The Effectiveness of Belt Systems in Frontal and Rollover Crashes. SAE 770148,1977.

(3) LANGWIEDER K.: Aspekte der Fahrzeugsicherheit anhand einer Untersuchung von realen Unfällen. Diss. 1975, TU Berlin.

(4) DAALGARD J.B. et al.: Rules and Experiences in Denmark/ Effect of Mandatory Seat Belt Legislation in Denmark. 6th IAATM Conf, 1977.

(5) VOIGT G., Krantz P.: Fatalities in Car Occupants in Sweden in 1975 and the Effect of Seat Belt Legislation. 6th IAATM Conf., 1977.

(6) WALZ F.: Der Einfluss von Sitzgurten und Kopfstützen auf die Verletzungen von Autoinsassen. Diss. 1972, University of Zurich.

(7) BOHLIN N.: A Statistical Analysis of 28'000 Accident Cases with Emphasis on Occupant Restraint Value. SAE 670925, 11th Stapp Conf.1967.

(8) PETTY P.G.: The Influence of Seat Belt Wearing on the Incidence of Severe Head Injury. 6th IAATM Conf., 1977.

(9) NORDENTOFT E.L. et al.: Effect of Mandatory Seat Belt Legislation in Denmark, with Special Regard to Minor and Moderate Injury. 6th IAATM Conf., 1977.

(10) SABEY B.E.: Alleviation of Injuries by Use of Seat Belts. LF 633, 6th IAATM Conf., 1977.

(11) HERBERT D.C., Vazey B.A., Henderson J.M.: Seat Belt Performance in Australia. Seat Belt Seminar, Melbourne, 1976.

(12) MACKAY G.M.: Belted Occupants in Frontal Crashes. 6th IAATM Conf., 1977.

(13) KAHANE Ch.J.: Usage and Effectiveness of Seat and Shoulder Belts in Rural Pennsylvania Accidents. NHTSA Technical Note N43-31-5,1974.

(14) HENDERSON J.M.: Some aspects of compulsory seat belt wearing in New South Wales, Australia. 5.Internat.Konf."Accident and Traffic Medicine", London, 2.Sept. 1975.

(15) CAMERON M.H. Nelson P.G.: Injury Pattern with and without Seat Belts. 6th IAATM Conf. 1977.

(16) JONES I.S.: Benefits of Restraint Use With Particular References to Accidents Involving Compartment Intrusion. Calspan Corp. Buffalo 1975.

(17) Beratungsstelle für Unfallverhütung, BfU, Berne, Wearing Rates of Seat Belts in Switzerland.

(18) NIEDERER P., Walz F., Zollinger U.: Reconstruction and Analysis of Lateral Collisions. IRCOBI proceedings 1977, Berlin.

(19) WALZ F., Niederer P., Zollinger U., Renfer A.: Analysis of 115 Killed and Severly Injured (OAIS 2) Seat Belt Users. 6th IAATM Conference, proceedings 1977, Melbourne.

(20) WALZ F.: Verletzungen der Brust-und Lendenwirbelsäule bei Gurtenträgern. To be published in Hefte zur Unfallheilkunde, Beiheft, 1977.

(21) WALZ F. et al.: Unfalluntersuchung Sicherheitsgurten, Eidg. Justiz-und Polizeidepartement, Berne, 1977.

(22) NIEDERER P., Walz F., Zollinger U.: Adverse Effects of Seat Belts and Causes of Belt Failures in severe Car Accidents in Switzerland during 1976. 21th Stapp Conf. New Orleans , Oct.1977.

(23) HARTEMANN F. et al: Occupant Protection in Lateral Impacts. 20th Stapp Conf. proceedings, 1976.