RECONSTRUCTION AND ANALYSIS OF LATERAL COLLISIONS

Peter Niederer Ph.D.
Institute for Biomedical Engineering
Swiss Federal Institute of Technology and
University of Zurich

Felix Walz M.D., Ulrich Zollinger M.D.
Institute of Forensic Medicine
University of Zurich

ABSTRACT

In 1976 a one year study on severely and fatally injured users of seat belts has been performed in Switzerland. During this program 304 accidents involving 410 persons (257 OAIS 2 - 6, 153 OAIS 6+) were investigated. In this report certain aspects of lateral collisions in connection with the data obtained in the field study are analysed. The average ISS for nearside and offside occupants is shown to increase significantly with increasing Δv, whereas the influence of the mass ratio of the involved vehicles is less pronounced. A mathematical simulation analysis of the influence of the intrusion and the lateral distance of the occupant from the impacted door on the attained shoulder force levels is demonstrated.

INTRODUCTION

In 1976 the Swiss Federal Police Administration initiated a one year study on severely and fatally injured users of seat belts in Switzerland in connection with a mandatory seat belt law effective

January 1, 1976. During this program 304 accidents involving 410 injured persons (257 OAIS 2 - 6, 153 OAIS 6+) were analysed. It was estimated {1}, that the sample contained 10% of all seat belt users which were injured with a severity of OAIS 2, 25% of the OAIS 3 cases, and 37% of the ones with OAIS 4 and 5. With regard to the fatalities the sample is complete.

As belt effectiveness has sufficiently been proven in field investigations in the past no comparative performance study was intended. Instead, specific problems were to be analysed including injury patterns of seat belt wearers, frequency and statistical significance of cases with adverse belt effects and belt failures. The applied methodology and the general results are published by Walz et al. {1} and Niederer et al. {2}. The relevant injury patterns are reported by Walz et al. {3, 4, 5}, while in {2} special attention is given to belt failures and adverse belt effects as well as to the correlation between injury severity and the relevant collision parameters, especially Δv[1)] and mass ratio[2)].

In this report certain aspects with regard to lateral collisions (3 and 9 o'clock impact direction) are treated. First, the influence of Δv and the mass ratio of the involved vehicles is established. Second, an occupant dynamics study with the aid of computer simulation demonstrates the dependence of the calculated peak shoulder force on the intrusion and on the lateral distance of the occupant from the impacted door.

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1) Δv is defined as the velocity change during the collision phase. This parameter is either estimated from the available documentation or calculated with the aid of SMAC (Simulation Model of Automobile Collisions, McHenry {6,7})unless a meaningful value cannot be assigned in a case (e.g. complex collisions).

2) The mass ratio is defined here as the ratio between the mass of the vehicle under consideration and its collision partner. With increasing mass of the collision partner, the mass ratio therefore decreases.

INFLUENCE OF ΔV AND MASS RATIO ON THE INJURY SEVERITY IN LATERAL COLLISIONS

For the whole sample a correlation analysis {e.g. 8} reveals {1,2} that both Δv and the mass ratio exhibit a statistically significant influence on the injury severity measured as average ISS {9}. If the same procedure is applied to the classes of nearside and offside occupants in collisions with a 3 and 9 o'clock impact direction the following results are obtained:

Δv:	nearside occupants, 33 cases:	r = .81 (***),	figure 1
	offside occupants, 16 cases:	r = .53 (*),	table 1
mass ratio:	nearside occupants:	r = .38 (*),	figure 2
	offside occupants:	r = .11 n.s.,	table 2

The influence of Δv is seen to be statistically significant for both nearside and offside occupants. In contrast to the frontal collisions {2}, the mass ratio appears to be of a lesser importance with the side collisions of the sample.

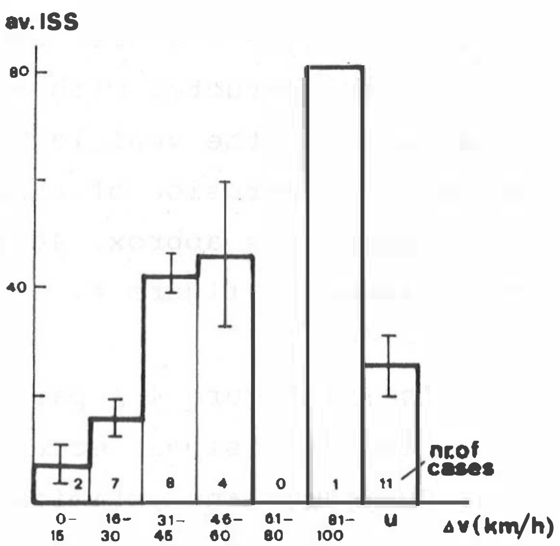


Fig. 1: Average ISS vs. Δv, nearside occupants

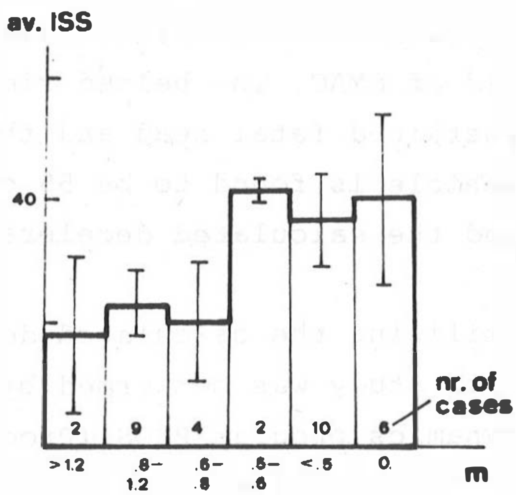


Fig. 2: Average ISS vs. mass ratio (m), nearside occupants

Δv km/h	av. ISS	s	nr. of cases
0 - 15	4	-	1
16 - 30	19.5	8.9	4
31 - 45	16.3	5.2	6
46 - 60	37.5	46	2
61 - 80	-	-	0
81 -100	54	-	1
unknown	13	9.9	2

Table 1: Average ISS vs. Δv, offside occupants (s: std. dev.)

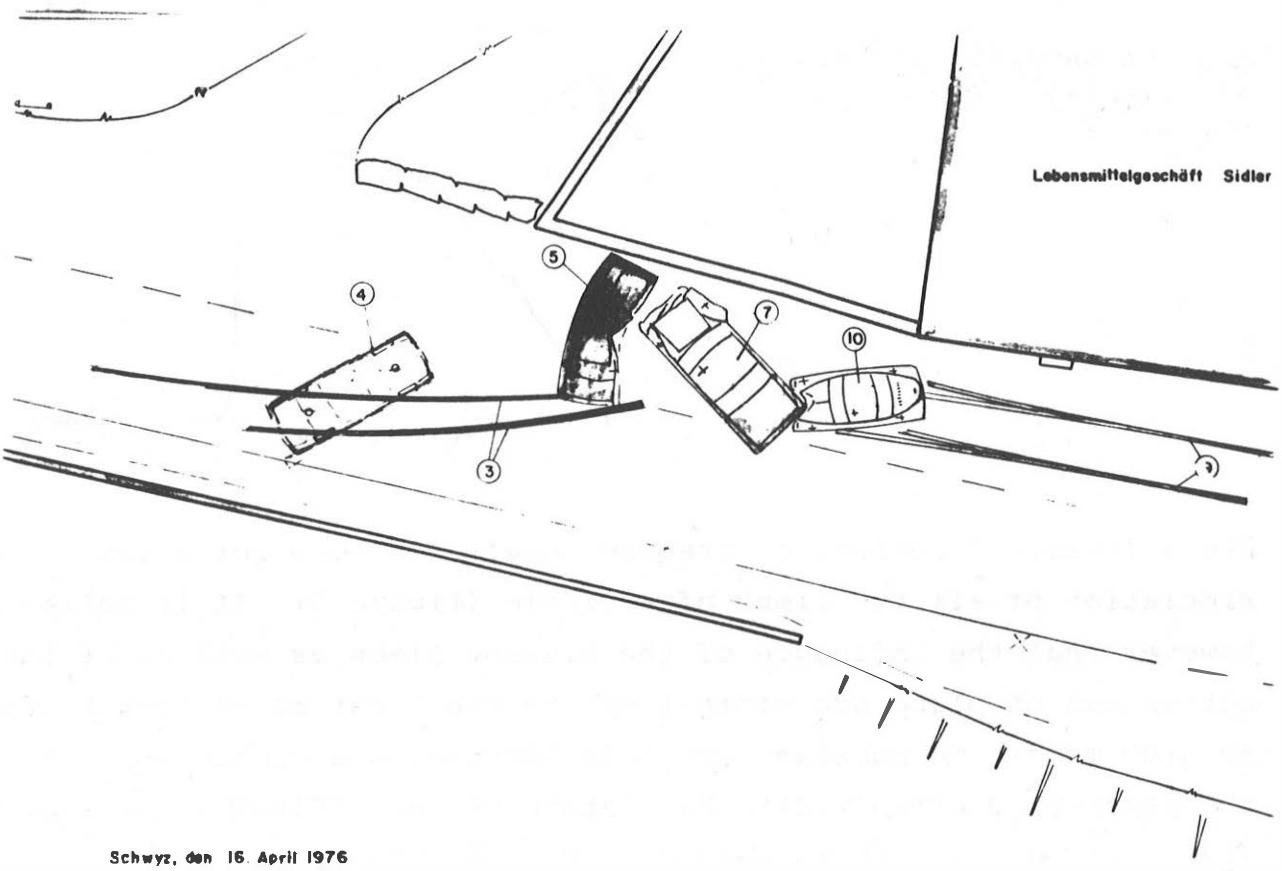
Mass ratio	av. ISS	s	nr. of cases
1.2	20	-	1
.8 - 1.2	13.6	6.9	5
.6 - .8	70	-	1
.5 - .6	8	-	1
.5	22.9	6.4	7
fixed obj.	9	-	1

Table 2: Average ISS vs. mass ratio, offside occupants

MATHEMATICAL SIMULATION OF LATERAL COLLISIONS

The available documentation on lateral deformation characteristics of vehicles is even less sufficient than the one in a frontal direction. The application of SMAC as well as the "hand" estimation of Δv is based to a considerable extent on the knowledge of deformation characteristics. However, in many cases of lateral collisions one of the involved vehicles experiences a frontal impact such that the relative extent of crush can serve as an indication of lateral deformability. As an example, in figure 3 a case of lateral collision is documented which was reconstructed with the aid of SMAC. The belted right front passenger in the vehicle V1 sustained fatal head and thorax injuries. The intrusion of this vehicle is found to be 55 cm, Δv was determined as approx. 46 km/h and the calculated deceleration curve is shown in figure 4.

Utilizing the calculated deceleration pulse of figure 4 a parametric study was performed by adapting the two dimensional occupant dynamics program PSOS (Program for the Simulation and Optimization of Safety Belts, Niederer {10}) to a lateral motion. Two dimensional simulation of side collisions has previously been made by Bowman et al. {11} using the MVMA 2D model (Robbins et al. {12}).



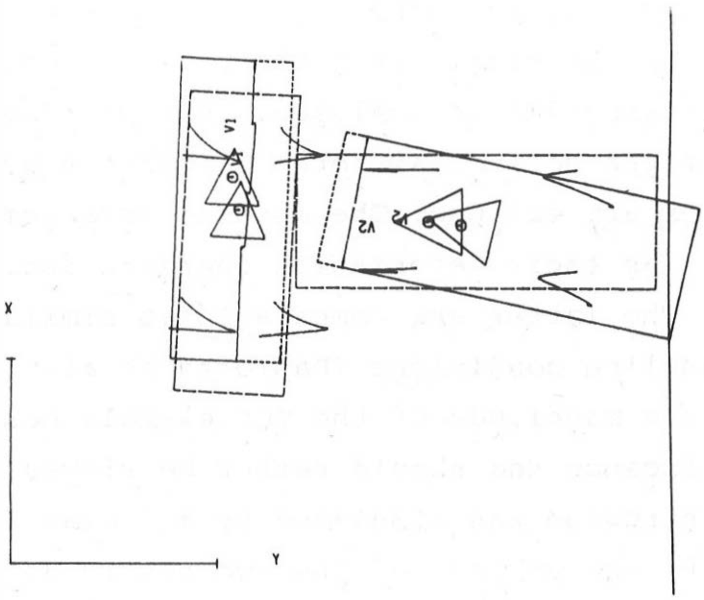
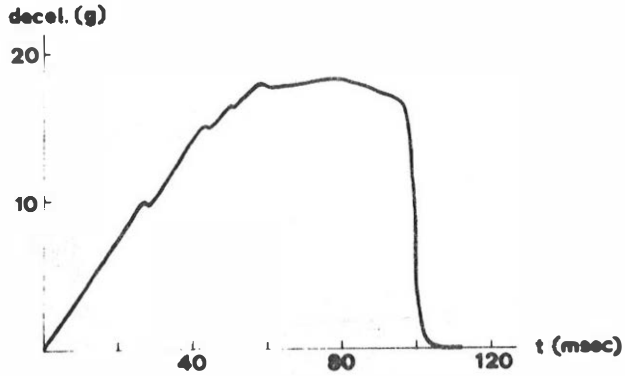


Fig. 3: Police documentation and SMAC reconstruction of a lateral collision between vehicle 5 (V1, see photograph at end of paper) and vehicle 7 (V2). The impact of vehicle 10 was of minor severity. The tire tracks 3 were caused by V1 (position 4 is an earlier phase) the tracks 9 by vehicle 10.

Fig. 4: Deceleration pulse as determined by SMAC for vehicle V1.



The 8 links, 10 degrees of freedom model PSOS does not allow for a simulation of all the limbs of a victim (figure 5). It is believed however that the influence of the missing limbs as well as of the motion out of plane are minimal during the first major impact (up to ∿100 msec). To substantiate this hypothesis a comparison with the Calspan 3D Crash Victim Simulation Program (Fleck et al.{13}, figure 6) was made which showed comparable results.

In the following, the influence of the intrusion I and the distance D of the head of the victim from the impacted door on the peak load exerted on the shoulder is analysed. This peak load is found as the maximal sum of the horizontal force components acting on the upper torso and upper arm ellipse. The assumed arrangement of the vehicle panels as well as their deformation characteristics are purely hypothetical. The latter are comparable to similar panels defining the MODROS baseline conditions (Danforth et al. {14}). The calculated absolute magnitude of the forcelevels has therefore a limited significance and should rather be viewed as reference value. The intrusion was simulated by a linear lateral motion with respect to the vehicle of the two panels defining the door and the window during the first 80 msec up to a prescribed displacement.

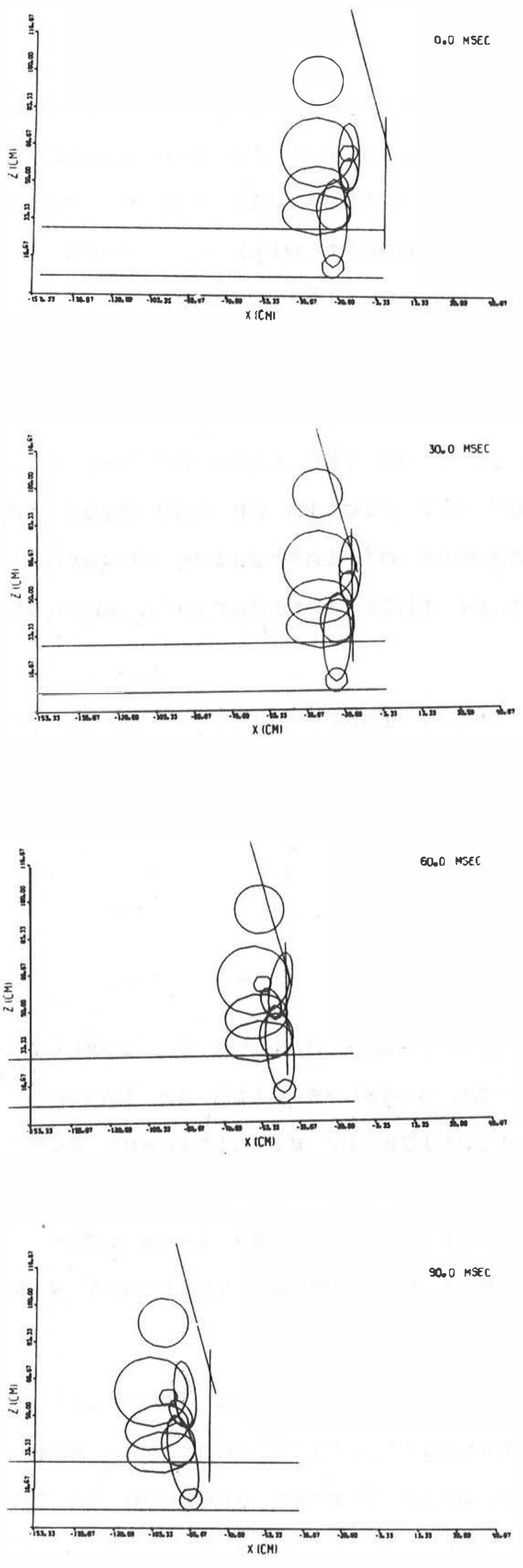


Fig. 5: Motion sequence of the two dimensional model PSOS in a side impact with intruding door and window panels. The side impact is defined by the deceleration pulse shown in figure 4. The intrusion is modelled by a relative motion of the door and window to the vehicle.

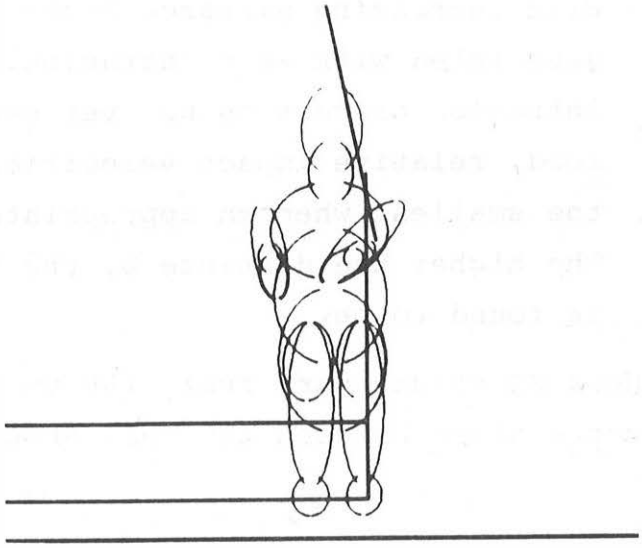


Fig. 6: Example of a side impact modelled with the Calspan 3 D Crash Victim Simulation Program.

The simulation results (figure 7) exhibit essentially two features:

- At smaller distances D, in general, lower peak force levels are obtained (unless the occupant has no contact with the impacted door), whereas with increasing intrusion the peak force increases also. This latter effect is in agreement with observed injury severity (Walz et al. {4}, Hartemann {15}, Jones {16}).
- With increasing distance D the minimal peak force is no longer associated with zero intrusion. In spite of the fact that the intrusion process is not yet completed at the time of maximal load, relative impact velocities of the victim on the door are the smallest when an appropriate amount of intrusion occurs. The higher the distance D, the higher this appropriate amount is found to be.

Head SI values vary from ∿150 up to ∿800. There exists no obvious correlation between the peak shoulder load and the head SI.

CONCLUSIONS

- In the sample of 33 nearside and 16 offside belted occupants who sustained injuries of OAIS $\geq$ 2 in crashes with an impact direction of 3 or 9 o'clock, a statistically significant dependence of the injury severity on Δv could be proven. In contrast to that, the influence of the mass ratio is less pronounced; with the offside victims no correlation is found with the injury severity.
- With increasing sitting distance from the impacted door (at least up to a value at which the occupant still contacts the door) and with increasing intrusion peak forces exerted on the shoulder generally increase also. However, at higher distances from the impacted door at the beginning of the crash the mini-

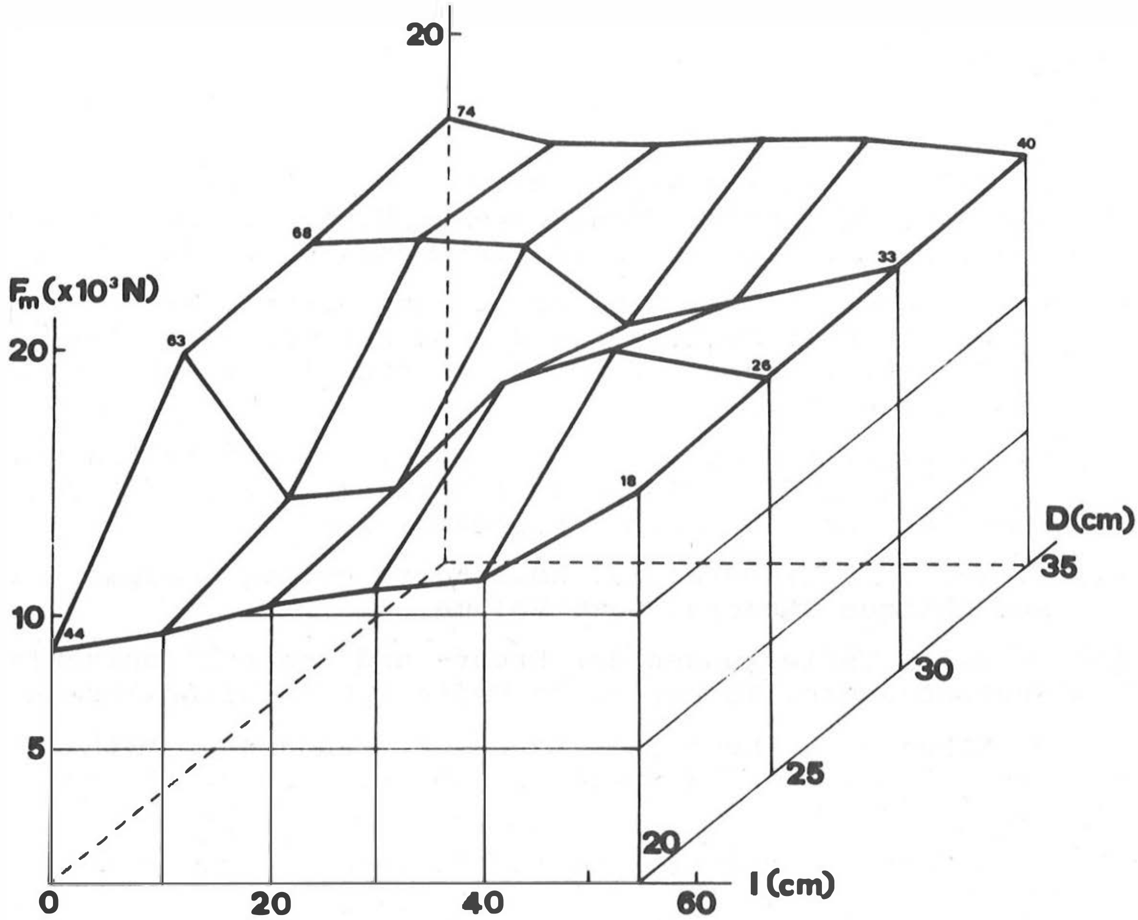


Fig. 7: Dependence of the peak shoulder force F_m on the intrusion I and the distance D between head and door. At D = 20 cm, the upper arm ellipse is approx. 1 cm apart from the door panel.

mal peak force need not be associated with no intrusion. With an appropriate amount of intrusion impact velocities of the body on the door can be reduced.

ACKNOWLEDGEMENTS

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Damage extent of vehicle V1 (see figure 3).