# Comparison of head injuries during small and moderate overlap in motor vehicle crashes

Junaid Shaikh, Bengt Pipkorn

## I. INTRODUCTION

Car occupant fatalities in Europe decreased by 29% between 2010 and 2019, but annual car occupant fatalities (44%) remain higher than the other road users [1]. The same trend can be observed in the USA, where car occupant fatalities are 43% per annum, the highest figure among road users [2]. Most car occupant fatalities in the USA occur in frontal collisions [2], of which small and moderate overlap crashes account for 24% [3].

In recent studies, the occupants in a small overlap crash [3] showed a higher risk (four times) of sustaining a head injury with a severity level of three or higher on the Abbreviated Injury Scale (AIS3+) [4] compared to the occupants in a moderate overlap crash [3], based on the US data [5]. However, using nine different injury criteria it was found that the AIS2+ head injury risk for small to moderate overlap is in the range of 0.4–1.2 [6]. The current study aims to investigate the occupant head injury risk in small and moderate overlap crashes using German data.

## II. METHODS

The current work used German In-Depth Accident Study (GIDAS) [7] 2020 December release. The data were weighted [8] towards German national data against the year of the accident, the severity of the accident, and the type of accident. The weight factor obtained by the weighting was noted against each case. Only cases (crash year: 1999–2020) with reconstruction were selected (N=39,756). The new model (first registration year≥2000) vehicles, having seats less than or equal to nine (official vehicle class=M1) or weight not exceeding 3.5 tons (official vehicle class=N1), involved in a single event, and no rollover or fire event, were chosen. Vehicles that skidded prior to crash, or collided with a motorcycle, bicycle, or pedestrian were excluded. Vehicles with frontal damage were considered (N=3,591). Drivers wearing a three-point seat belt and not ejected were selected (N=3,075). The dataset (N=407) was filtered for vehicles having a small overlap or a moderate overlap. The small overlap was defined as “direct damage due to impact covering up to 1/4$^{th}$ of the vehicle’s width from the left excluding chassis beam” (vehicle deformation index-3=20), while moderate overlap was defined as “direct damage due to impact covering up to 1/3$^{rd}$ of the vehicle’s width from the left including chassis beam or half of the vehicle’s width from the left with less than fifty percent direct damage” (vehicle deformation index-3=21 or 81). Finally, vehicles in the small and moderate overlap that experienced large deformation, which is defined as vehicles deformed beyond half of the hood in the longitudinal direction and below the lower edge of the windshield, were considered for analysis (N=88; see Fig. A1). The weight factors against the cases in the final dataset (N=88) were then normalised [8], so that the sum of the weighted numbers is equal to the unweighted sample size but representative of German national statistics. The current work used the 2015 version of the abbreviated injury scale (AIS). Drivers’ injury and injury overview data were retrieved and all drivers having an AIS2+ injury were marked.

### *Head Injury Risk*

The AIS2+ head injury risk was estimated for small and moderate overlap using Equation (1) and normalised weighted numbers. The relative risk of AIS2+ head injury risk for small to moderate overlap was calculated using Equation (2). A 95% confidence interval (CI) for relative risk was calculated using p-bootstrap with the weighted data [9].

$$AIS2+head\ injury\ risk\ (\%) = \frac{no.of\ drivers\ with\ AIS2{+}head\ injury_{[type\ of\ overlap]}}{Total\ drivers\ exposed\ with\ high\ severity\ crash_{[type\ of\ overlap]}} * 100 \quad (1)$$

$$Relative\ risk = \frac{AIS2{+}Head\ injury\ risk_{[small\ overlap]}}{AIS2{+}Head\ injury\ risk_{[moderate\ \ overlap]}} \quad (2)$$

J. Shaikh (junaid.shaikh@autoliv.com; +91-9821617552) is a Project Tech Lead – Traffic Safety Research at Autoliv India Pvt. Ltd, Bangalore, India. B. Pipkorn is an Adjunct Professor at Chalmers University of Technology, Gothenburg, and Director of Simulation and Active Structures at Autoliv Research, Vårgårda, Sweden.

## III. INITIAL FINDINGS

Of 88 vehicles (or drivers) that experienced large deformations, 19.9 experienced small overlap and the remaining 68.1 had moderate overlap. There were 15.8 AIS0 (uninjured), 1.6 AIS1 (minor injury), and 2.5 AIS2 (moderate injury) drivers with head injury in small overlap. In moderate overlap injury severity was comparatively lower, with 59.6 AIS0, 2.4 AIS1, and 6.2 AIS2 drivers with head injury. None of the drivers had AIS3 (serious) or higher severity head injury. The median of the model year for both (small and moderate overlap) groups was 2005 (interquartile range (IQR): small overlap – 6.3; moderate overlap – 8). Males were dominant in both groups: small overlap – 79.2%, and moderate overlap – 66.3%. The median age of drivers among the small overlap group was 42.7 years (IQR: 25.6 years), while for the moderate overlap it was 41.6 years (IQR: 32 years).

The AIS2+ head injury risk for small overlap was 12.6% and for moderate overlap it was 9%. Among small and moderate overlaps, 2.5 (12.5%) and seven (10%) drivers had a concussive head injury. The relative AIS2+ head injury risk between small to moderate overlap was 1.4 (95% CI: 0.0–5.2) indicating that the AIS2+ head injury risk in small overlap is not very different from the risk in the moderate overlap by trend.

## IV. DISCUSSION

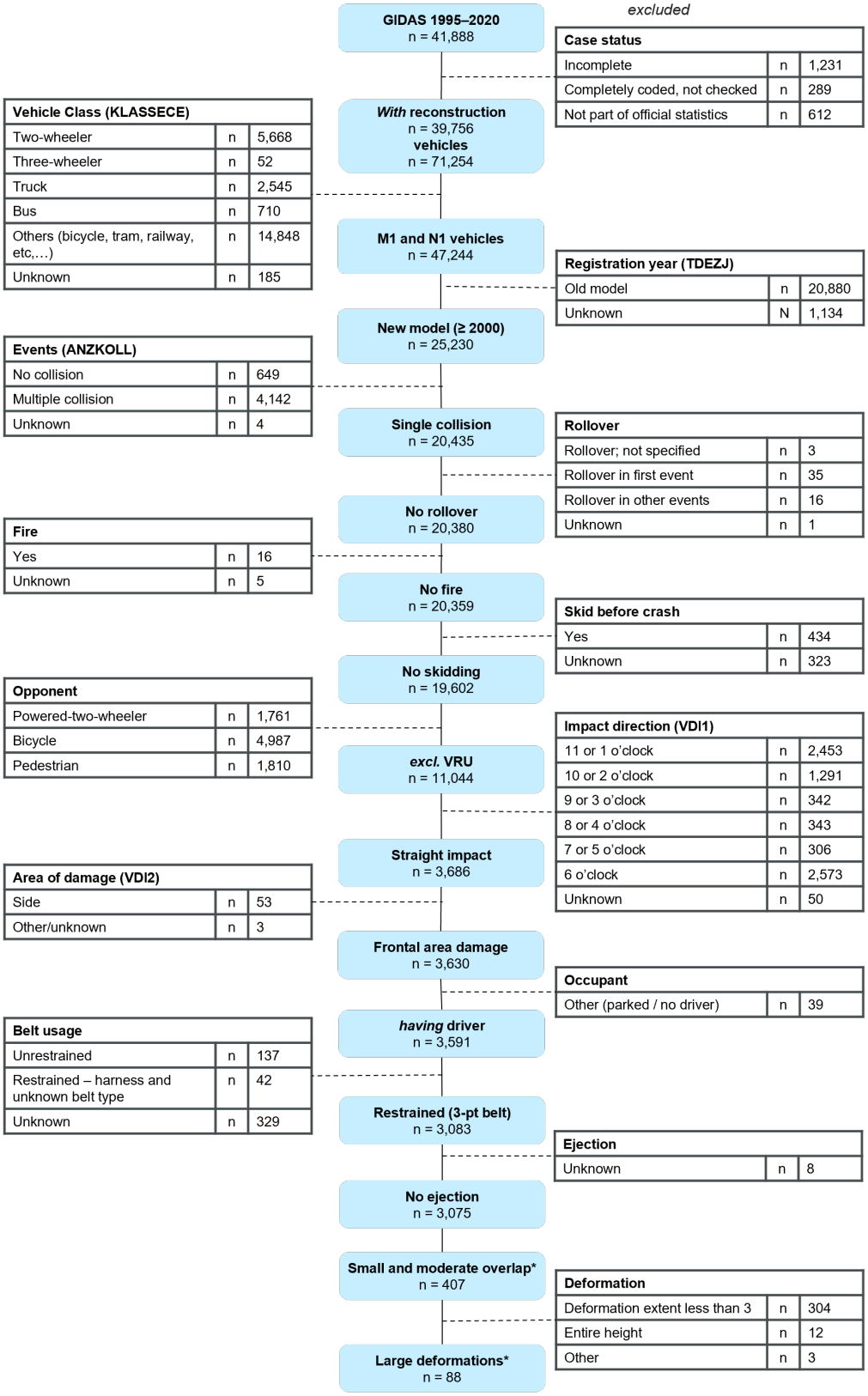
A 12.6% AIS2+ head injury risk was found for small overlap crashes, which is close to the 10% injury risk found with NASS CDS data [6]. However, in the same study [6] a 2.3% head injury risk was found in moderate overlap crashes, which is substantially smaller than the 9% risk found in this study. In addition, by trend, the relative risk of 1.4 that was found for small to moderate overlap is also smaller than the 4.3 that was found with NASS data [6]. However, the wide confidence interval in the current study indicates the relative risk of 1.4 is merely by trend and requires more data in future to have statistical evidence. One of the reasons for the difference in injury risk between the current (GIDAS) and the previous (NASS CDS) study could be the method of classifying the small and moderate overlap. In the current study, photographs were not used to confirm the damage and the extent of deformation to the longitudinal member. Therefore, there can be crashes without large deformations but coded as large deformations and vice versa. Another reason could be the difference in the vehicle fleet. The difference in vehicle design between European and US vehicles could influence the performance in small and moderate overlap crashes.

On the contrary, the head injury risks found in this study are supported by injury risks predicted by the finite element (FE) head model developed at the Royal Institute of Technology (KTH) [10] and by the Strasbourg University Finite Element Head Model (SUFEHM) [11] in small and moderate overlap crashes [6]. The head injury risks were predicted with the FE head models by driving the models with data from the head of the Hybrid-III and Test Device for Human Occupant Restraint (THOR) in small and moderate overlap crash tests. For small and moderate overlap crashes, a 12.6% and 9% AIS2+ head injury risk was found, while KTH and SUFEHM head models predicted a 12% risk for both overlap crashes, respectively. Based on the findings using GIDAS data, the FE head models seem to be able to predict head injury risk in small and moderate overlap crashes.

## V. REFERENCES

[1] European Commission, Facts and Figures Car occupants, 2021.
[2] NCSA, Traffic safety facts 2019, 2021.
[3] Brumbelow, M. L., *et al*., ESV, 2009.
[4] AAAM, Abbreviated injury scale, 1998.
[5] Mueller, B., *et al*., ESV, 2015.
[6] van Slagmaat, M., *et al*., TIP, 2019.
[7] Hautzinger, H., *et al*., ESAR, 2004.
[8] Sander, U., *et al*., AAP, 2018.
[9] Efron, B., *et al*., CRC press, 1994.
[10] Kleiven, S., *et al*., *J Biomech*, 2002.
[11] Deck, C., *et al*., *J Crashworthiness*, 1998.

# VI. APPENDIX




* details defined in the method section of the paper

Fig. A1. Schematic representation of filters provided in the study.