

## Upper-body injuries in pedestrians hit by the car front

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### I. INTRODUCTION

When investigating the mitigation and prevention of injuries in pedestrians hit by cars, vehicle testing is performed at collision speeds up to 40 km/h, addressing head, pelvis and lower extremities injuries. While those body regions are the most frequently affected, the upper-body might deserve attention, too. Various studies have considered different injury severities, different definitions of thorax, chest or torso, and different impact opponents [1-6]. However, the need to protect pedestrians from upper-body injuries in inevitable impacts remains to be discussed. In this study, road traffic crashes are analysed to identify if and which kind of pedestrian upper-body injuries caused by impact with the car front could be mitigated or prevented through vehicle design.

### II. METHODS

Pedestrian accident cases from the German In-Depth Accident Study (GIDAS) up to July 2020 were selected, applying the following inclusion criteria: only two participants (one vehicle, one pedestrian); vehicle category N1 or M1; pedestrian first hit by the central 75% of the width and within the first 1000 mm in x-direction of the vehicle front; accident year >2005; manufacturing year of vehicle >1996; collision speed, including tolerance, is 50 km/h at maximum. By excluding crashes with cars equipped with front crash bars, with pedestrians using e.g. sports equipment, perambulators or walking aids, with pedestrians lying or kneeling on the street, and with pedestrians with unknown MAIS (maximum AIS (Abbreviated Injury Scale) value), we arrived at 451 pedestrians to be included in the analysis.

Of those 451 relevant cases, 161 pedestrians (36%) showed at least one AIS2+ injury (coded by AIS© 2005 update 2008) [7], in 88% the Injury Severity Score (ISS) was lower than 15, and in two cases the ISS was 75. The 408 AIS2+ injuries are grouped into body regions as defined in [8] and descriptively analysed on the first 4 digit level. The injury-causing vehicle structures and impact locations contained in the GIDAS data set were cross-tabulated with the injuries. In this study the upper-body was defined based on AIS codes, including: AIS region 4 (thorax), thoracic spine, liver, spleen, kidneys, clavicle, scapula, proximal humerus, acromioclavicular-, sternoclavicular-, and glenohumeral-joint.

### III. INITIAL FINDINGS

The vehicle accounts for 281 out of the 408 AIS2+ injuries (69%). Table I details the vehicle structures causing the injuries separately for the different body regions as defined in [8].

The "Head & face" region is most frequently injured by ground impact followed by the windscreen. The "Upper Extremities" region is also most frequently injured by ground impact followed by the bonnet. Furthermore, the bonnet is also the most frequent injury causing part of the body regions "Thorax & Thoracic Spine" and "Abdomen & Lumbar Spine". The "Pelvis (Bone and pelvic content)" region is most frequently injured by the bonnet leading edge and "Lower Extremities" by the bumper.

When focusing on the upper-body, it was found that 85 AIS2+ injuries occurred in 43 pedestrians. With 42% (36 of 85 injuries, occurring in 21 pedestrians), the bonnet was the most frequent cause of AIS2+ upper-body injuries (Table II). The bonnet impact caused especially fractures of the proximal humerus and of the thoracic vertebra, and lead to lung and kidney injuries.

TABLE I

INJURY CAUSING PART/LOCATION OF IMPACT OF 408 AIS2+ INJURIES IN 161 PEDESTRIANS BY BODY REGION [8]

	Head & face	Neck & Cervical Spine	Thorax & Thoracic Spine	Abdomen & Lumbar Spine	Pelvis (Bone and pelvic content)	Upper Extremities	Lower Extremities	sum
Road surface (flat)	44	2	8	1	4	29	7	95
Front bumper	0	0	0	0	0	0	84	84
Bonnet	7	0	20	14	6	20	2	69
Windscreen	23	3	4	6	0	5	0	38
Vehicle front	3	1	7	2	2	0	18	33
Bonnet leading edge	0	0	1	3	14	1	3	22
A-pillar	7	3	0	1	0	1	0	12
Unknown	3	0	1	0	0	2	6	12
Own body movement	1	2	1	0	0	0	5	9
Other vehicle parts*	3	0	1	0	3	3	10	23
Other environment**	2	1	6	1	0	0	1	11
Sum	93	12	49	28	29	61	136	408

\* Sum of 12 different named vehicle structures, \*\* sum of three different named environmental structures

TABLE II

INJURY-CAUSING STRUCTURE/LOCATION OF IMPACT OF 85 UPPER-BODY AIS2+ INJURIES (4 DIGIT LEVEL WITH AIS SEVERITIES OCCURRING IN DATA) IN 43 PEDESTRIANS

	own body movement	unknown	road surface (flat)	road surface (uneven)	kerb stone edge	fence	vehicle front	bonnet leading edge	bonnet	rear end of bonnet	windscreen wipers	windscreen	A-pillar	front door	sum	
Rib Cage (AIS2, AIS3, AIS4)			6	1		1			3	1		2			14	
Prox. humerus fracture (AIS2)			4						6			1			11	
TS Vertebra/Disc injury (AIS2, AIS3)	1					1	1		5			1			9	
Lung (AIS2, AIS3)			1			1	2	1	3						8	
Kidney (AIS2)							1	1	4						6	
Scapula fracture (AIS2)		1	3									1		1	6	
Hemothorax (AIS2, AIS3)			1		1		1		2						5	
Clavicle (AIS2)									2		1	1	1		5	
Sternum (AIS2)		1					1		2						4	
Glenohumeral joint (AIS2)		1							2			1			4	
Liver (AIS2)							1					1			2	
Thorax Other named veins (AIS2)				1											1	
Heart (Myocardium) (AIS6)							1								1	
Pleura (AIS2)							1								1	
TS Cord injury (AIS5)												1			1	
Seven different injuries*									7						7	
Sum		1	3	15	2	1	3	9	2	36	1	1	9	1	1	85

\*each injury occurring once: Aorta, thoracic (AIS4)/ Pulmonary artery (AIS5)/ Thorax Vena cava (AIS3)/ Diaphragm (AIS3)/ Pericardium (AIS2)/ Spleen (AIS3)/ Sternoclavicular joint (AIS2)

IV. DISCUSSION

In all, 36% (161 out of 451) of the selected pedestrian sample suffered from AIS2+ injuries. Those were most frequently caused by ground impact, followed by front bumper and bonnet. However, it must be noted that this ranking is also due to the not always clearly defined boundaries between vehicle parts, i.e. “vehicle front” may refer to front bumper, bonnet, windscreen, or bonnet leading edge. The bonnet caused 42% of the upper-body AIS2+ injuries. While testing procedures focusing on most frequently found injury-causing objects (bumper, front) are related to lower extremity injuries analyzed in this study, this cannot always be claimed for testing procedures focusing on other body regions, as demonstrated by the headform test procedures: While the windscreen including its periphery such as A-Pillars seems to be a predominant injury causing vehicle part to the

head, this is not the case with the bonnet. It is concluded, from these preliminary findings, that upper-body injuries deserve a more detailed analysis in terms of injury-causing contacts to the vehicle. As the first analyses reveal, balancing attention to vehicle structures and ground impact remains a challenge.

#### V. REFERENCES

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