INJURY OUTCOMES IN SIDE IMPACTS INVOLVING MODERN PASSENGER CARS

Ruth Welsh
Andrew Morris
Vehicle Safety Research Centre
Loughborough University
UK
Ahamedali Hassan
Birmingham Automotive Safety Centre
The University of Birmingham
UK
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ABSTRACT

This study examines some characteristics of side impact crashes involving modern passenger cars. The UK National Accident Database (STATS 19) and UK In-depth Accident Database (CCIS) were analysed to determine crash characteristics and injury outcomes in side impacts. UK national accident data (300,000 road crash records per year) shows clear improvements in injury outcomes in side impacts when a sample of 'older' vehicle designs are compared to 'newer' vehicle designs. In-depth accident data was analysed to understand the nature and circumstances of crashes in which injury occurred.

Analysis of the characteristics of such crashes which resulted in serious injury suggests that the conditions in terms of collision speed and height of impact (on the struck vehicle) do not usually match those of the UNECE R95 test specification, but impact angle is in agreement.

In terms of AIS2+ injury outcomes in modern vehicles, head (28% of AIS2+ injuries to front seat occupants) and chest injuries (22%) still predominate although injuries to the abdomen (10%), upper extremity (14%) and lower extremity (including pelvis 19%) are also observed. When only AIS4+ injuries are considered, head (36%), chest (41.3%) and abdomen injuries (30.5%) comprise the overwhelming majority of injuries. The type of injury (in terms of anatomical location) was then considered together with injury contact source.

In conclusion, rates of serious injury outcome are highest in non-oblique impact modes, in accordance with the current regulatory test. The in-depth data indicate that serious injury occurs at speeds exceeding those in the current regulatory test and that a sizable proportion of bullet vehicles engage at a height above that used for the MDB in the regulatory test. Modifications to the current regulatory test procedure should be considered in order to ensure that regulation is more representative of the real world accident situation.

INTRODUCTION

Struck side impacts have always presented an engineering design challenge in terms of provision of good protection to vehicle occupants. In the main, this is because there is generally so little space between the occupant and the striking object which reduces the scope for providing crash energy management unlike the situation in frontal impacts. Therefore in many cases, the occupants can be subjected to a very severe impact to the side of the vehicle. The seat belt can offer only reduced protective benefits compared to frontal impacts simply because of the lack of ride-down space and the seat belt geometry; occupants can slip easily out of the seat belt in side impacts. Additionally, because of the seated position of the occupants, there is potential for ejection of the head through the side window aperture and consequent exterior head contact.

Regulations governing design of vehicles for side impact crashes were introduced in the European Union in 1996 (UNECE R95). In many cases, the regulation implied a change of vehicle design so that acceptable levels of protection were provided specifically to the head, chest and pelvis. As a consequence, vehicles manufactured after the introduction of the regulation were generally somewhat structurally different to vehicles manufactured earlier. In the UNECE R95 test procedure, the Mobile Deformable Barrier (MDB) impacts the test vehicle at 50km/h and at 90-degrees. No attempt is made to simulate the movement of the target vehicle. The lateral striking position is aligned with the occupant seating position rather than the vehicle wheelbase with the MDB centred on the R-point. The introduction of the EuroNCAP programme has also contributed to a change in design because in order to obtain a maximum 5-star occupant protection rating, vehicles are required to undergo a pole impact test. In order to perform well in the pole impact test, such vehicles need to be equipped with an effective head protection device (such as side curtain, Inflatable Tubular System (ITS)) designed to prevent head contacts directly on the pole. Since

the introduction of the regulation and also EuroNCAP, some studies have examined the changes that have been introduced from an injury perspective. However, lack of field data in the UK has prevented a rigorous examination of effectiveness.
This study examines UK field data to explore a number of specific issues;

- What has been the overall change in struck-side casualty figures in the UK as a result of the changes in vehicle design;
- How do injury rates vary between regulatory and non-regulatory struck-side crash characteristics?
- What are the most common AIS2+ injuries (and their respective contact sources) that occur in struck side impact crashes to occupants of modern European passenger cars.

METHODOLOGY

Two data sources have been used in this study:
In the first part an analysis has been made of the UK National Accident Data (STATS 19). The STATS 19 data contains information relating to UK accidents resulting in human injury or death but does not contain any information relating to non-injury accidents. The data gives a full representation of the accident situation within the UK but is limited in respect of detailed vehicle damage and casualty injury information. Data for the years 2001-2003 were used for this analysis and cars selected for inclusion based upon their year of manufacture. Two distinct groups were defined; old vehicles manufactured 1990-1992 (distinctly pre regulation and new vehicles manufactured 2001-2003 – distinctly post regulation An exploration was made of the relative Killed or Seriously Injured (KSI) rates for drivers in the two scenarios, car to car and car to non-car struck-side impacts. The impact type was necessarily categorised according to the STATS 19 variable 'first point of impact' and is subjective to the attending police officer; it does not imply but gives an indication of the direction of force (DoF) of the impact. The occupant severity is as judged by the attending police officer at the time of the accident unless death subsequently occurs within 30 days of the accident.
The results shown in parts 2 and 3 involve analysis of UK in-depth crash injury data (CCIS). The data for these analyses were collected between June 1998 and February 2005. The CCIS data use a stratified sampling criterion to identify crashes to be investigated; 100% of fatal, 80% of serious and 10-15% of slight injury crashes (according to the UK Government's accident classification) that occur within specified geographical regions throughout the UK are investigated. The sampling criteria also specify that injury must have occurred in at least one car that was at most 7 years old at the time of the accident. All vehicles in the study were towed away from the crash scene and an in-depth examination of each vehicle was made in recovery-yards and garages within a few days of the accident. All injuries were coded using the Abbreviated Injury Scale (AIS) 1990 revision. Data were obtained medical records held by hospitals to which the crash casualties were admitted. For the purposes of the analyses presented, the data were selected so that vehicles sustained only <u>one impact</u> in order to more accurately relate the injury outcome to the specific impact event. Furthermore, selection was made on the age of the vehicle so that consideration was given only to those manufactured 1998 onwards. Data on only restrained front seat occupants was considered. Where appropriate, data on drivers and front seat passengers were combined to provide a larger sample of 'struck-side' occupants for analysis.

RESULTS

PART 1 – UK National Data (STATS 19) analysis

In this section an analysis has been made of the STATS 19 data for the years 2001-2003. Data are recorded for injured occupants and although information can be derived from the data for uninjured drivers, this is not the case for front seat passengers (FSP). Thus, in order to best comprehend how injury rates have changed with vehicle design modification, the analysis is restricted to drivers in right-side crashes. The data are still limited in respect of the population under consideration; an injury has to have occurred to a road user for inclusion in the STATS19 database. Hence the analysis does not support conclusion relating towards complete injury mitigation.
Two scenarios, car to car impacts (generally covered by regulation) and car to non-car impacts (not generally covered by regulation), are considered. The car-to-non-car impacts exclude impacts with vulnerable road users. It is not possible to determine restraint use or airbag deployment from the STATS19 data but it is considered that patterns of belt use would not have changed significantly during the three years worth of data analysed in the study. This is supported by observational studies carried out in the UK (TRL 2002, 2004). The effect that belt use has in side impact protection is also somewhat limited.
The population sizes for this analysis are given in Table 1.

Table 1.
Population size struck-side crashes STATS 19 2001-2003

	DRIVER	
	Old cars	New cars
Car to Car	7,841	6,800
Car to non-car	6,130	5,940

Table 2 shows how the proportion of drivers killed or seriously injured in struck-side impacts has changed with vehicle age. Struck side impacts are defined as right side impacts for drivers (assuming vehicles to be right hand drive). The KSI rate is lower in the new cars for both of the impact scenarios considered.

Table 2.
KSI rates in struck-side crashes STATS 19 2001-2003

	DRIVER	
	Old cars	New cars
Car to Car	4.9%	3.8%
Car to non-car	7.0%	4.8%

Table 3 shows the percentage reduction in the KSI rates comparing the post-regulatory cars to those manufactured earlier.

Table 3.
Percentage reduction in KSI rates for struck-side crashes STATS 19 2001-2003

	DRIVER
Car to Car	22.4%
Car to non-car	31.4%

There is some variation in the amount of benefit that has been seen in the scenarios considered. Whilst the reduction for car to car impacts is 22.4%, the benefit in car to non car impacts is even greater at 31.4%.

Table 4.
Fatality rates in struck-side crashes STATS 19 2001-2003

	DRIVER	
	Old cars	New cars
Car to Car	0.6%	0.4%
Car to non-car	1.5%	0.7%

Table 5.
Percentage reduction in KSI rates for struck-side crashes STATS 19 2001-2003

	DRIVER
Car to Car	33.3%
Car to non-car	53.3%

When fatalities alone are considered, the rates among injured occupants are shown in Table 4 and the percentage reduction in the rate of fatality in Table 5.

Table 4 shows that the fatality rates have also dropped in post-regulatory cars compared with earlier design for both car to car and car to non-car impacts. The percentage reduction in fatalities is more marked than when considering those also seriously injured. Of note here is the broad categorisation of injury outcome used within the STATS19 data. Whilst a life saved reduces the fatality count, reducing a severe injury to a moderate or serious injury (e.g. bi-lateral rib fractures with hemothorax to simple unilateral rib fractures) does not alter the 'serious' casualty classification, thus improvements within the 'serious' injury outcome category are difficult to gauge.

It is apparent from these results that newer vehicle design has benefited drivers in struck-side impacts. It also clear that for this impact type, in the event of injury, KSI outcome and indeed fatality is more likely in impacts other than car-to-car impacts, such impacts are not currently being considered in compulsory regulatory testing.

PART 2 – In-depth data analysis - struck side impacts in relation to the regulatory test procedure

This analysis uses the UK in-depth accident data (CCIS) to examine injury severity by body region to front seat occupants in car-to-car struck side crashes in newer model vehicles (1998 onwards). These are considered in relation to some characteristics of the ECE R95 crash test procedure, the direction of force of the impact and the closing speed of the impact. Some examination of the impacting height of the bullet vehicle in relation to the target vehicle's sill height is also made.

(a) Direction of Force (DoF) Three scenarios were analysed; all Directions of Force including side-swipe type impacts (158 occupants), non-oblique impacts (3 o'clock and 9 o'clock - 36 occupants) and oblique frontal angles (2 o'clock and 10 o'clock - 40 occupants).

Table 6.
MAIS – struck side front occupants – all body regions

	All Dof	**Non-Oblique**	**Oblique**
MAIS 0,1	72.8 %	58.3 %	72.5 %
MAIS 2,3	17.1 %	27.8 %	17.5 %
MAIS 4+	5.7 %	13.9 %	5.0 %
Not Known	4.4 %	0 %	5.0 %

Table 6 shows the MAIS score across all body regions. The lowest rate of MAIS 0, 1 injury outcome occurs in crashes in which a non-oblique direction of force and consequently there is a higher rate of Serious injury outcome (MAIS 2, 3 – 27.8%) and MAIS 4+ (13.9%).

Injuries to the different body regions were then considered, specifically those to the head, chest and pelvis. Table 7 shows the Maximum AIS score to the head.

Table 7.
Max AIS head – struck side front occupants

	All Dof	Non Oblique	Oblique
Max AIS 0,1	83.5 %	80.6 %	77.5 %
Max AIS 2,3	10.1 %	13.8 %	17.5 %
Max AIS 4+	1.9 %	5.6 %	0 %
Not Known	4.5 %	0 %	5 %

Serious head injury is most prevalent in non-oblique impacts, followed by oblique impacts; both rates are higher than when all directions of force are considered together.

For chest injury (Table 8) the rate of MAIS 2+ injury is considerably higher in non oblique impacts (27.8%) than for the oblique (7.5%) and when all directions of force are considered together (11.3%).

Table 8.
Max AIS chest – struck side front occupants

	All Dof	Non Oblique	Oblique
Max AIS 0,1	84.2 %	72.2 %	87.5 %
Max AIS 2,3	7.0 %	16.7 %	2.5 %
Max AIS 4+	4.3 %	11.1 %	5.0 %
Not Known	4.5 %	0 %	5.0 %

A similar situation occurs for pelvic injuries (Table 9). Here, the rate of serious injury in non oblique impacts is 13.9% compared with 5% in oblique impacts and 6.3% for struck side impacts in general.

It is evident from the data presented in Tables 6-9 that more serious injury outcome occurs in impacts with a purely perpendicular lateral component.

Table 9.
Max AIS pelvis– struck side front occupants

	All Dof	Non Oblique	Oblique
Max AIS 0,1	89.2 %	86.1 %	90.0 %
Max AIS 2,3	5.7 %	11.1 %	5.0 %
Max AIS 4+	0.6 %	2.8%	0 %
Not Known	4.5 %	0 %	5.0 %

(b) Closing speed As a measure of the impact severity, the closing speeds (km/h) for side impacts in which there was a car to car impact have been calculated (where the data allowed). The closing speeds for crashes involving 73 struck side occupants in newer model cars are shown in Table 10.

Table 10.
Closing speeds, struck side occupants (N=73)

	25th percentile	50th percentile	75th percentile
All severities	34.5 km/h	46 km/h	65.0 km/h
MAIS 2+	43.5 km/h	62 km/h	76 km/h
MAIS 3+	46 km/h	70 km/h	81 km/h
Fatalities	71 km/h	76 km/h	90.8 km/h

When all occupant severities are considered, the 50th percentile closing speed is a little lower than the current test speed (50 km/h). However, when considering occupants with 'Serious' injury outcome (MAIS 2+ and MAIS 3+) a higher closing speed distribution is observed and the 25th percentile is closer to the current test speed. The closing speed for fatalities far exceeds the current test speed.

It should be noted that the sample size used here is small (73 struck side occupants) since substantial pre-selection on a data set comprising only newer cars has been made and both cars in the accident needed to have a recorded Delta-V in order to calculate the closing speed. However the results are in accordance with previous work (Thomas et al, 2003). Both this and the previous study indicate that Serious injury is prevalent and more frequent at impact speeds exceeding the current test speed and consideration should be given to increasing the test speed in order to better reflect the crash circumstances under which Serious injury still occurs in newer cars.

(c)Impact Height An analysis was then made of car-to-car impacts where the impact on the struck side was into the passenger compartment i.e.

middle third of the car (266 occupants). The analysis was made on an occupant basis to establish the proportion of occupants exposed to conditions where the sill has been overridden.

In 64% of cases, there was direct contact upon the sill, however the variable used in the analysis does indicate whether there was or was not an override of the sill at the same time. In 88 out of the 266 cases examined the bottom of the direct contact of the bullet car was clearly above the sill height for the struck side occupant, a third of cases. This is considered an underestimate of the number of cases since this represents full override and does not include cases where partial override may have occurred. In those cases where full override occurred, over two thirds of the bullet cars have a reported effective stiff structure height greater than 390mm the current height of the MDB used in European regulation. It is important to note that the lower stiff structures on car fronts may be set more rearwards so it is possible that considerable intrusion can occur from override even when there is good later stage structural engagement.

Part 3 – AIS 2+ injuries in struck side impacts in newer vehicles

Front seat occupants of post regulatory cars in struck side crashes, irrespective of direction of force, are considered in this section. The data comprise 317 occupants with an overall injury outcome as shown in Table 11.

Table 11.
Front occupant injury outcome in struck side impacts

	N	%
Fatal	27	8.5%
Serious	74	23.3%
Slight	177	55.8%
Uninjured	39	12.3%
Total	317	100

The KSI rate in this data set is somewhat higher than presented in part 1 (STATS19 data) since the CCIS data are biased towards serious injury outcome. However, the purpose of the analysis in this section is to examine the ***type*** of serious injury experienced by struck side occupants and so the sample bias does not affect the conclusions in this case.

In the subsequent analysis, the 350 AIS2+ injuries sustained by the 317 front seat occupants in struck side crashes are examined in more detail. Table 12 shows the breakdown according to AIS injury severity of the AIS 2+ injuries. A little under half of the AIS 2+ injuries are in fact AIS 2, a further 29.7% are AIS 3 and the remaining 23.8% are AIS 4 and above.

Table 12.
Severity of injuries to front occupants in struck side impacts

	N	%
AIS 2	163	46.6
AIS 3	104	29.7
AIS 4	50	14.3
AIS 5	24	6.9
AIS 6	9	2.6
Total	350	100

The distribution of the 350 AIS 2+ injuries across the various body regions is shown in figure 1. The largest proportion occurs to the head followed by the chest then the lower extremity.

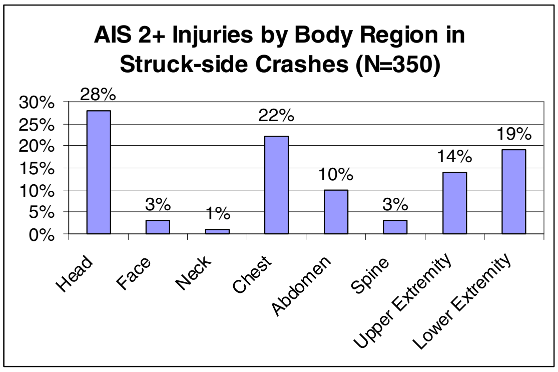

Figure 1. AIS 2+ Injuries by body region in struck-side crashes.

The data were then studied to examine injured body region by AIS score. Injuries to the head, chest, abdomen, upper and lower extremity (including pelvis) only have been included in this analysis since they are the only body regions which contribute more than 10% of the total number of AIS2+ injuries. This analysis is as shown in Table 13.

Table 13.
AIS2+ injuries to body regions

	AIS 2,3 N=267	AIS 4+ N=83
Head (N=97)	64%	36%
Chest (N=80)	58.8%	41.2%
Abdomen (N=36)	69.5%	30.5%
Upper limb (N=48)	100%	-
Lower limb (N=67)	100%	-

It can be seen from Table 13 that injuries to the upper and lower extremity are not particularly life-threatening since they are all rated as AIS 3 and below. However, the debilitating effects of AIS 2 and AIS 3 lower limb and in particular foot/ankle injuries should not be under-estimated (Morris et

al, 2006). For head, chest and abdominal injury, of those rating AIS2+, a further 30-40% rate as 4+. AIS 4+ injuries represent a greater threat-to-life particularly when multiplicity of injury occurs.
The next analysis examines injury types for the main body regions injured. These are as shown in Tables 14 to 18.

Table 14.
Head injury typology in struck-side impacts

INJURY TYPE	N	% (OF ALL AIS2+ INJURIES)
Cerebrum injury (including contusion, laceration, haematoma, cerebral oedema, etc)	44	12.6
Skull fracture (including fracture to skull base and vault)	26	7.4
Unconsciousness for more than 1 hour	14	4.0
Other injury (including brain-stem, cerebellum etc)	13	3.7
Total	97	

Table 14 shows that injuries to the cerebrum are a particularly common injury in struck-side impact crashes followed by skull fractures. In many cases, these injuries occur simultaneously but this study has not examined multiplicity of injury. In total, cerebrum injuries comprise almost 13% of the total number of AIS 2+ injuries in struck-side impacts.

Table 15.
Chest injury typology in struck-side impacts

INJURY TYPE	N	% (OF ALL AIS 2+ INJURIES)
Up to 3 fractured ribs	17	4.9
More than 3 fractured ribs	14	4.0
Sternum fracture	7	2.0
Lung injury (including contusion, laceration)	27	7.7
Aorta laceration	5	1.4
Other injury	10	2.9
Total	80	

As can be seen from Table 15, fractures to the ribs in struck-side impacts (at all severities) comprise 9% of the total number of AIS2+ injuries in struck-side impacts. However, lung injuries (including particularly laceration and contusion) are also relatively frequent. Again, rib fractures and lung injuries do occur simultaneously but this effect has not been considered in this study.

Table 16.
Abdomen injury typology in struck-side impacts

INJURY TYPE	N	% (OF ALL AIS2+ INJURIES)
Liver injury (including laceration, contusion)	16	4.6
Spleen injury (including laceration, rupture)	12	3.4
Other injury	8	2.3
Total	36	

In Table 16, AIS 2+ abdominal injuries do not occur nearly as frequently in struck-side impacts when compared to injuries in other body regions. However, injuries to this body region do comprise over 10% of the total numbers of injuries in side impacts. Furthermore, just under one-third of abdominal injuries are rated as AIS 4+ and are thus associated with a relatively high risk of mortality.

Table 17.
Upper extremity injury typology in struck-side impacts

INJURY TYPE	N	% (OF ALL AIS 2+ INJURIES)
Clavicle fractures	16	4.6
Ulna/radius fracture	15	4.3
Humerus fracture	6	1.7
Metacarpus/carpus	5	1.4
Other	6	1.7
Total	48	

Whilst AIS 2+ upper extremity injuries are relatively common in side impacts, they are not usually rated above AIS 3 in terms of threat-to-life. Clavicle, radius and ulna fractures were found to be the most common injury types in side impacts as shown in Table 17.

Table 18.
Lower extremity injury typology in struck-side impacts

INJURY TYPE	N	% (OF ALL AIS 2+ INJURIES)
Pelvic fracture	25	7.1
Femur fracture (shaft, trochanter, condylar)	19	5.4
Tibia	8	2.3
Fibula	7	2.0
Other	9	2.6
Total	67	

Table 18 shows that pelvic and femur fractures make up the majority of AIS 2+ lower extremity injuries in side impacts comprising 12.5% of the total number of AIS 2+ injuries. Below-knee injuries were relatively uncommon in comparison and foot/ankle fractures were found to be very rare in side impacts. However, all of the lower extremity injuries were rated as AIS 2 or 3 and are thus associated with a low probability of mortality.

The injuries described above make up 94% (from Tables 14-18) of the total injuries that were sustained by struck-side front-seat occupants in side impact crashes.

Contact sources for these AIS2+ injuries were then analysed in order to establish the most frequent source of contact in (or exterior to) the vehicle. These are as shown in Table 19, which shows a number of interesting findings. Firstly, AIS 2+ head injuries were found to be associated with contacts on exterior objects usually the exterior surfaces of bullet vehicles and also direct contact on poles and trees. When head contact on the vehicle interior surface occurred, it usually involved interaction with the A or B pillar or the header-rail. Chest injuries tended to occur as a result of contact with the door which was also the case for abdominal injury in high severity crashes. The door region was also responsible for injuries to the upper and lower extremity. It is interesting to note that the airbag (both side/frontal) was thought to be responsible for approximately 10% of injuries to the upper extremity although whether this is due to direct interaction with the airbag or through 'fling' onto interior surfaces is uncertain.

Table 19.
Contact sources for AIS 2+ injuries in struck-side impacts

MAIN INJURY CONTACT SOURCES	1	2	3
Head	External contact (54%)	B-Pillar (19%)	A-Pillar (10%)
Chest	Door/B-pillar (68%)	Seatbelt (10%)	External contact (8%)
Abdomen	Door/B-pillar (56%)	Not known (22%)	External contact (17%)
Upper Extremity	Door (63%)	Not known (13%)	Airbag restraint (10%)
Lower Extremity	Door/ footwell (68%)	Footwell/ Facia (30%)	-

DISCUSSION

This paper highlights the success of regulation and also EuroNCAP in improving vehicle design for better crash protection. Benefits are clearly seen for drivers involved in struck side impacts. Changes that have been made and have given an apparent benefit to drivers in struck side in car-to-car impacts have also benefited drivers in struck side car-to-non-car impacts.

Despite the enormous improvements to vehicles in terms of safety, most vehicle occupants who are killed in side impact crashes die as a result of sustaining head or chest injury. Whilst there is some activity on-going in terms of head protection (e.g. EEVC proposed test procedure, optional pole-test as part of EuroNCAP, head protection airbags/ side curtains), there is no specific procedure to exclusively consider chest protection, although side airbag technology is available. Additionally, a recent study by Morris et al (2005) indicated that whilst head bags seemed to offer increased protection in struck-side impacts, the same was not evident for chest bags, particularly those that were seat mounted.

The remaining problem for chest injury is somewhat surprising since the vehicle industry can meet the requirements of the current regulations governing side impact (i.e. UN-ECE R95) relatively easily and no issues concerning chest injury are detected in compliance testing. This could be because many vehicles are designed such that loading is applied directly from the vehicle B-pillar/door structure to the pelvis thereby removing the potential for loading via intrusion to the thorax by pushing the dummy sideways. However, the same will only apply in real-world situations if the transfer of load from the pelvis to the chest through the lumbar spine is correctly represented in the test dummy. This is probably not achieved in the EuroSID dummy but could be better predicted by the WorldSID dummy.

The analysis of injury severity in relation to the direction of force confirms that, in newer model cars, higher rates of Serious injury outcome for struck side occupants are apparent in non oblique impacts compared with oblique impacts and struck side impacts on the whole (irrespective of the direction of force). This is particularly the case for the chest, abdomen, pelvis and struck side limbs but not the case for head impacts.

With respect to the impact speed, it is evident that in newer model cars 'Serious' injury outcome occurs at crash speeds above that used in the current crash test. In order to predict and monitor these Serious injuries, consideration should be given to modifying the existing side impact test speed to better reflect that in which Serious injury occurs in real world crash situations.

A sizeable proportion of bullet cars contact the case car above sill height. It is anticipated that this proportion will grow as SUV/MPV type vehicles become increasingly more prevalent in the fleet. Consideration should be given to the structure and point of impact of the Mobile Deformable Barrier (MDB) in the side impact test procedure in light of the changing vehicle fleet.

Current test procedures only represent car-to-car impacts - however car to pole impacts are an important consideration (highlighted here in the analysis of injury contact sources, particularly for head injuries). EEVC have developed a pole-test procedure which could be used to monitor the situation for head protection but further modifications would be required to address chest protection in pole impacts.

Serious chest and abdominal injuries are however more likely to occur through direct contact with the intruding side door. Devices such as door and seat mounted chest air bags have been introduced to cushion the effects. However, as previously mentioned, there is no evidence to show that these have been effective. Continued monitoring of the effectiveness of side airbags is required including an assessment of the situation for out of position occupants with a view to the development of pre-crash sensing that would allow for early deployment. Additional countermeasures could include increased bolstering/padding of the interior door surfaces.

A further consideration, though not examined in the analysis presented here, is the interaction effect on struck-side occupants of non-struck side and rear seat occupants. The European regulation only requires a dummy in the front struck-side position. There is potential to make better use of other empty seats in order to monitor occupant interaction in the current test.

CONCLUSIONS

- Post regulatory vehicles offer improved protection for front occupant in struck-side crashes
- Rates of serious injury outcome are highest in non-oblique impact modes, in accordance with the current regulatory test.
- However, the CCIS data indicate that serious injury occurs at speeds exceeding those in the current regulatory test and that a sizable proportion of bullet vehicle engage at a height above that used for the MDB in the regulatory test.
- Serious head and chest injuries continue to present a threat to life in post regulatory vehicles, for head injuries the major contact source is with an external object (bullet vehicle, tree, pole) whilst for chest injuries the most prevalent contact source is the side door.
- A continued monitoring of the effectiveness of side airbag protection is required.
- Modifications to the current regulatory test procedure should be considered in order to ensure that the test best represents the real world accident situation that reflects more involvement of newer cars with improved safety.

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Further information on CCIS can be found at http://www.ukccis.com/