CAR TO CAR STRUCK SIDE IMPACTS – A COMPARISON BETWEEN EUROPEAN ACCIDENT DATA AND DIRECTIVE 96/27/EC

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ABSTRACT

This paper summarises the main results of a European Enhanced Vehicle-Safety Committee (EEVC) analysis of accident data from the UK and Germany conducted by EEVC WG 21 'Accident Studies' for EEVC WG13 'Side Impact' to inform the further development of side impact test procedures for cars. An overview showing the relative frequency of car to car side impacts within the accident population is presented. The distribution of variables within real world accident data relating to the dummy, the mass of the test barrier and the test configuration (impact angle, impact location and speed) are compared to the specification within the European Side Impact Directive (96/27/EC).

Keywords: Side impacts, Regulations, Accident Analysis

THIS PAPER PROVIDES A SUMMARY OF THE KEY FINDINGS of an analysis of accident data concerning side impacts. The analysis has been conducted by the European Enhanced Vehicle Safety Committee (EEVC), Working Group 21 (Accident Studies) and has been requested by EEVC Working Group 13 (Side Impact) as part of its work to raise the levels of side impact protection of cars.

The paper describes the results of an in-depth analysis of car to car side collisions focussing on the in-depth accident data from the UK and Germany. A related paper (Thomas et al 2009) provides an overview of side impacts using national accident data from the UK, France and Sweden and a further related paper (Otte et al 2009) summarises the results of the analysis of accidents involving cars sustaining side impacts with poles using in-depth data also from the UK, Germany, and Sweden.

The European side impact test procedure is enacted within Directive 96/27/EC and requires cars to maintain a specified level of protection when struck in the side by a mobile barrier travelling at 50km/hr. There have been a number of previous studies that have evaluated the frequency and characteristics of side impacts although few have covered more than a single member State. The EU Directive included a requirement that it be evaluated after two years and Edwards et al (2001) undertook this under the auspices of the EEVC. They concluded that the test speed should be increased and that the use of a pole test be considered. Similar conclusions were reached by Hassan et al (1999) who examined both UK CCIS data and US NASS data files. Frampton et al (2000) highlighted the frequency of injuries to non-struck (far) side occupants. Thomas et al (2003) reviewed UK in-depth accident data and confirmed that more car occupants in newer passenger cars (<7 years old at the time of the crash) died as a result of side impacts than frontal crashes, that single impacts with poles were nearly as frequent as car to car side collisions and that the side impact test speed was substantially below that of the speed involved in the majority of fatal crashes.

Hassan et al (2006) looked at specific injury types in side impact crashes involving passenger cars of "newer" design (those manufactured between 2001 and 2003). In terms of AIS2+ injury outcomes in the study, head (28% of the total numbers of AIS2+ injuries to front seat occupants) and chest injuries (22%) predominated although injuries to the abdomen (10%), upper extremity (14%) and lower extremity (including pelvis – 19%) are also observed. When only AIS4+ injuries were considered, head (36%), chest (41%) and abdomen injuries (30%) comprised the overwhelming majority of injuries. Injuries to the cerebrum (N=44) made up almost 13% of the entire sample of

AIS2+ injuries in side impacts followed by lung injuries (8%), skull fractures (7%) and pelvic fractures (7 %).

This study was therefore undertaken in order to realise the extent of car-to-car side impacts within the accident constellation and secondly to examine the characteristics of car-to-car struck-side impacts occurring in relation to the current regulatory crash test specifications. Consideration was given to occupant characteristics, impact characteristics and injury outcomes in order to assess the validity of proposed changes to the side impact regulatory test procedure.

In particular, field accident data from two European in-depth databases were analysed to explore a number of issues to assess the validity of the suggested changes to the current regulatory compliance testing procedure governing vehicle design for side impact protection. Therefore the field data were explored to look at;

- What are the effects of the absence or presence of an adjacent occupant on injury outcomes in side impact crashes;
- The common crash characteristics in terms of impact severity, Direction of Force (DoF) and impact location;
- What are the characteristics of the 'striking' or 'bullet' vehicle in side impacts (in terms of the mass) and how does this influence injury outcome to occupants of the 'struck' vehicle;
- What are the most common AIS2+ injuries (and their respective contact source) that now occur in side impact crashes to occupants of modern vehicles.

DATA SOURCES

Data used in the analysis undertaken were drawn from two in-depth accident data sets;

- **Co-operative Crash Injury Study (CCIS) UK (Accidents occurring 1998-2006)**
  CCIS retrospectively examines accident damaged cars in which the occupants have been injured. Medical information is collected and collated against the vehicle damage. Vehicle examinations include an assessment of the performance of the vehicle structure and whether it was a factor in any resulting occupant injury. The CCIS database employs sampling criteria based upon vehicle age and injury outcome. To be included, the accident must have involved a passenger car less than 7 years old in which an occupant was injured. Additionally the car must have been towed away from the accident scene. CCIS is a statistically significant sample of passenger car accidents in the UK. Investigations are carried out for around 80% of serious and fatal and 10-15% of slight injury accidents occurring in selected geographical regions.
- **GIDAS, Germany 1999-2005 (Accidents occurring 1999-2005)**
  The GIDAS database covers all road users and employs an on scene investigation method. Based upon a full-scale sketch of the accident scene and the vehicle deformations, every accident is reconstructed. Data are collected from two research areas, Dresden and Hanover. These areas are extremely representative of the average German Topography and since the accidents are investigated by a statistical sampling plan, the GIDAS data is considered to be representative of the accident constellation in Germany.

METHODOLOGY

The basis of the study was the statistical analysis of in-depth accident data bases available within Europe. The analysis is spilt into two sections; the first identifies the proportion of side accidents within the data sets that, in broad terms, match the specification of Regulation 95 whilst the second takes these accidents and examines in further detail the variation in key variables that describe the test specification.

SECTION 1 In this section the base line data are selected to be occupants of newer cars manufactured from 1998 onwards where a side impact occurred as part of the crash sequence. Data from the CCIS (n=3,534 occupants) are included in this section. Subsequent selection criteria are applied to establish the proportion of Struck Side (SS) occupants in accidents with a single impact with a passenger car where no rollover occurred. Further selection is made based upon location of the damage to the struck vehicle and direction of force of the impact.

SECTION 2 In this section the base line data are further selected to contain SS front occupants of newer (1998 onwards) cars in accidents with a single impact with a passenger car where no rollover occurred and some damage was evident to the passenger compartment. Data from both CCIS (n=155) and GIDAS (n=54) are included in this section. Analyses are undertaken that examine firstly the occupant seating position in relation to overall injury outcome, secondly provide an overview of the vehicle and impact characteristics and thirdly analyse the belted struck-side occupants' injury outcome in relation to the crash characteristics prescribed by the regulatory crash test. The results were synthesised in order to provide where possible comments on the Regulation 95 test configuration and the Advanced European Mobile Deformable Barrier (AE-MDB) in relation to the dummy (sole occupancy, injury prediction) the mass of the barrier and the impact configuration (impact angle, location and speed).

RESULTS

SECTION 1 EXTENT OF REGULATION 95 TYPE SIDE IMPACTS IN THE SIDE IMPACT CONSTELLATION. In the CCIS data, 44% of occupants in newer cars experience a side impact as part of their crash sequence. Table 1 describes the distribution of crash configuration for the 3,390 CCIS occupants where a side impact was part of the crash sequence. It can be seen that for all accidents where a side impact occurs 45% are single impacts with no rollover.

Table 1. Side impact crash configuration CCIS

	No Rollover	Rollover	Total
Single impact	1534 (45.3 %)	503 (14.8 %)	2037 (60.1 %)
Multiple impacts	1191 (35.1 %)	162 (4.8 %)	1353 (39.9 %)
Total	2725 (80.4 %)	665 (19.6 %)	3390 (100 %)

For the 1,534 occupants (CCIS) in a single impact with no rollover, the distribution of impact object is shown in table 2.

Table 2. Impact object – single side impacts, no rollovers

	CCIS (1534 occupants)
Car	899 (58.6%)
Two wheeled motor vehicle	27 (1.8%)
MPV/Light Goods Vehicle	105 (6.8%)
Heavy Goods Vehicle	135 (8.8%)
Narrow object < 41 cm	98 (6.4%)
Wide object > 41 cm	251 (16.4%)
Other	0 (0%)
Not Known	19 (1.2%)
Total	1534 (100%)

Table 2 shows that passenger cars are most frequently the impact object in single side impacts with no rollover (59% CCIS). Considering all of the occupants in some form of side impact, 3,390 (CCIS), 899 (27%) have a single impact to a passenger car with no rollover. Of these 899, 492 are struck side occupants. Thus struck side occupants in single car to car impact with no rollover comprise 15% of all of the occupants in newer cars exposed to a side impact as part of the crash event (492 of 3,390).Continuing the data selection further according to the specification within Directive 96/27/EC by firstly eliminating any side swipe type impacts, then selecting impacts where damage occurred to the passenger compartment and finally selecting the perpendicular impacts results in a sample of just 1% of the total occupants in side impacts (34 out of 3,390) (table 3). This suggests that approximately

1% of all occupants have an accident that is broadly comparable to the test as specified and applied in regulation 95. Selecting on impact speed would further reduce this proportion.

Table 3. Proportion of Reg 95 type impacts – all MAIS

Selection*	n	%**
Side impact occupants	3390	100%
Single impact, no rollover	1534	45%
Car to car	899	27%
Struck side	475	14%
No side swipe	373	11%
Damage including passenger compartment	237	7%
Damage only to passenger compartment	102	3%
Perpendicular impacts (3 and 9 o'clock DoF)	34	1%
MIAS 2+	20	0.6%

*Each row represents a further selection on the data in the row above
**The % is that remaining of the total number of side occupants when each successive selection is applied to the data

The analysis was repeated for fatal occupants and showed that just 2% (5 out of 239) of accidents with fatal outcome are broadly comparable to Reg 95. It should however be noted that some of the side impacts experienced as part of a multi mode crash sequence would be covered by the regulation.

SECTION 2 SIDE IMPACT CHARACTERISTICS IN COMPARISION TO REGULATION 95
The results presented in this section are a ***summary of the key findings*** from a substantial piece of analysis undertaken on behalf of the EEVC WG13 'Side Impact'.

In this section the CCIS and GIDAS data have been selected according to the following criteria;

- Belted struck side occupants;
- Vehicles manufactured 1998 onwards;
- Single side impact with no rollover or side swipe;
- Car to car impacts;
- Damage to, but not restricted to, the passenger compartment.

In both data sets (CCIS and GIDAS) the proportion of rear seat occupants is 10%. The analysis focuses on the front seat occupants resulting in a sample size of 155 for CCIS and 54 for GIDAS. Where possible both data sets have been used in each analysis. There are however some instances where a dual analysis is not appropriate due to restrictions associated with the sample sizes.

In the current side impact test a single occupant is represented in the driver's position. An analysis was made that considers the distribution of front seat occupancy for the SS occupants and the proportion of cases with an adjacent occupant. This has been done in relation to injury outcome. Table 4 shows the MAIS distribution according to seating position for the GIDAS data whilst table 5 shows the same distribution but including the distributions according to adjacent seat occupancy.

Table 4. Seat position for SS front occs by MAIS – GIDAS / CCIS

	GIDAS		CCIS	
	Driver n=37 (68.5%) (12 with adjacent FSP)	FSP n=17 (31.5%)	Driver n= 122 (78.7%) (48 with adjacent FSP)	FSP n=33 (21.3%)
MAIS 0	16 (44.4%)	8 (50%)	5 (4.3%)	2 (6.5%)
MAIS 1	17 (47.2%)	8 (50%)	71 (60.7%)	15 (48.4%)
MAIS 2	3 (8.3%)	0	21 (17.9%)	3 (9.7%)
MAIS 3+	0	0	20 (17.1%)	11 (35.4%)
Total	36 (100%)	16 (100%)	117 (100%)	31 (100%)
n/k	1	1	5	2

Table 5. Seat position for SS front occs by MAIS and adjacent occupant – CCIS

	Driver without adjacent passenger n=74 (47.7%)	Driver with adjacent passenger n=48 (31.0%)	FSP n=33 (21.3%)
MAIS 0	3 (4.3%)	2 (4.2%)	2 (6.5%)
MAIS 1	45 (65.2%)	26 (54.2%)	15 (48.4%)
MAIS 2	12 (17.4%)	9 (18.8%)	3 (9.7%)
MAIS 3+	9 (13.1%)	11 (22.8%)	11 (35.4%)
Total	69 (100%)	48 (100%)	31 (100%)
n/k	5	0	2

For the GIDAS data presented in table 4, all of the FSPs clearly have an adjacent driver (17) whilst 12 of the drivers had an adjacent FSP hence 54% (29/54) of the SS occupants have an accompanying NSS occupant. For the CCIS data the result is comparable with 52% (81/155) SS occupants having an accompanying NSS occupant. Considering the larger data set presented in table 5, SS occupants with an adjacent NSS occupant have a higher injury distribution than low SS occupants. The MAIS 3+ rate for lone drivers is 13% compared to 23% for drivers with an FSP present and 35% for FSPs.

With the change in vehicle design in order to meet the frontal impact regulatory test procedure cars have become heavier and hence the average mass of the vehicle fleet is increasing. An analysis has been undertaken to firstly establish the mass of the bullet vehicle in relation to the current MDB mass (950kg) and secondly to investigate the relationship between the mass of the bullet vehicle and the injury outcome for the belted occupants under the current selection criteria. For the analysis relating to bullet mass, 119 CCIS and 53 GIDAS cases are included. The remaining cases have missing data for the bullet mass.

Table 6. Bullet vehicle mass kg

	Minimum	Maximum	Mean
CCIS n=119	780	2465	1260
GIDAS n=53	806	1633	1225

For both data sets, the average mass of the bullet vehicle (1260/1225) is in excess of the mass of the current MDB (Table 6).

Tables 7-10 describe the injury outcome for the belted SS occupants according to the mass of the bullet vehicle. The bullet vehicles have been banded into 4 groups; <1000kg, 1000-1250kg, 1251-1500kg and >1500 kg. Tables 7 and 8 show the MAIS distribution within each of these groups for the CCIS and the GIDAS data respectively. Tables 9 and 10 give the rate of AIS 2+ and AIS 3+ injury respectively on an occupant basis across the different body regions (CCIS only). Further missing data relating to the AIS score for each body region reduces the sample to either 115 or 116 occupants.

Table 7. MAIS within Bullet Mass Group - CCIS

	< 1000 kg n=19	1000-1250 kg n=46	1251-1500 kg n=42	>1500 kg n=12
MAIS 0	5.3%	4.5%	2.4%	0
MAIS 1	57.8%	59.1%	39.0%	83.3%
MAIS 2	5.3%	18.2%	22.0%	0
MAIS 3+	31.6%	18.2%	36.6%	16.7%
Total	100%	100%	100%	100%
Fatal	10.5%	11.4%	16.7%	8.3%

Table 8. MAIS within Bullet Mass Group - GIDAS

	< 1000 kg n=8*	1000-1250 kg n=22	1251-1500 kg n=16	>1500 kg n=7*
MAIS 0	62.5%	52.4%	26.7%	42.9%
MAIS 1	37.5%	38.1%	66.7%	57.1%
MAIS 2	0	9.5%	6.7%	0
MAIS 3+	0	0	0	0
Total	100%	100%	100%	100%
Fatal	0	0	0	0

*Percentages should be interpreted with caution due to the low n

Table 9. Rate of AIS 2+ Injury within Bullet Mass Group - CCIS

	< 1000 kg	1000-1250 kg	1251-1500 kg	>1500 kg
Head n=115	5.6%	11.4%	29.3%	8.3%
Chest n=116	21.1%	25.0%	31.7%	16.7%
Upper Ex n=115	10.5%	2.3%	12.2%	0
Abdomen n=116	10.5%	9.1%	12.2%	8.3%
Spine n=116	5.3%	2.3%	9.8%	0
Pelvis n=116	21.1%	13.6%	17.1%	8.3%
Lower Ex n=116	10.5%	4.5%	12.2%	8.3%

Table 10. Rate of AIS 3+ Injury within Bullet Mass Group - CCIS

	< 1000 kg	1000-1250 kg	1251-1500 kg	>1500 kg
Head n=115	5.5%	9.1%	19.5%	8.3%
Chest n=116	21.1%	15.9%	29.3%	16.7%
Upper Ex n=115	0	0	0	0
Abdomen n=116	0	4.5%	4.9%	8.3%
Spine n=116	0	2.3%	0	0
Pelvis n=116	5.3%	4.5%	4.9%	0
Lower Ex n=116	10.5%	2.3%	4.9%	8.3%

There is no clear difference in MAIS across the different bullet mass groups, the chi-square for occurrence of MAIS 3+ (CCIS) is non-significant ($\chi^2 = 4.426$, d.f. =3, p=0.219). Higher rates of AIS 2+ and AIS 3+ head and chest injury are observed in the 1251-1500kg group compared to the 1000-1250kg group.

The next analysis considers the direction of force (DoF) of the impact. The current test procedure specifies a perpendicular impact. For the purposes of this analysis the direction of force of the impact has been categorised into three groups. Frontal oblique is defined as 1, 2, 10 and 11 o'clock impacts, perpendicular as 3 and 9 o'clock and rear oblique as 4, 5, 7 and 8 o'clock. Missing data relating to DoF reduces the CCIS sample to 148 occupants and the GIDAS sample to 52 occupants in tables 11 and 12 whilst further missing data relating to some body region injuries reduces the CCIS sample at times to 147 in tables 13 and 14.

Table 11. MAIS within DoF group – CCIS

	Frontal Oblique N=86 (58%)	Perpendicular N=44 (30%)	Rear Oblique N=18 (12%)
MAIS 0	3.5%	2.3%	16.7%
MAIS 1	70.9%	38.6%	44.4%
MAIS 2	11.6%	22.7%	22.2%
MAIS 3+	14.0%	36.4%	16.7%
Total	100%	100%	100%
Fatal	8.1%	15.9%	5.5%

Table 12. MAIS within DoF group - GIDAS

	Frontal Oblique N=33 (63%)	Perpendicular N=14 (27%)	Rear Oblique N=5 (10%)*
MAIS 0	45.5%	50.0%	40.0%
MAIS 1	51.5%	42.9%	40.0%
MAIS 2	3.0%	7.1%	20.0%
MAIS 3+	0	0	0
Total	100%	100%	100%
Fatal	-	-	-

*Percentages should be interpreted with caution due to the low n

Table 13. Rate of AIS 2+ Injury within DOF band - CCIS

	F Oblique	Perpendicular	R Oblique
Head n=147	9.3%	29.5%	0
Chest n=148	14.0%	34.1%	16.7%
Upper Extremity n=147	3.5%	9.1%	11.1%
Abdomen n=148	4.7%	15.9%	5.6%
Spine n=148	5.8%	2.3%	5.6%
Pelvis n=148	9.3%	22.7%	11.1%
Lower Extremity n=148	4.7%	11.4%	11.1%

Table 14. Rate of AIS 3+ Injury within DOF band - CCIS

	F Oblique	Perpendicular	R Oblique
Head n=147	5.8%	20.5%	0
Chest n=148	9.3%	31.8%	16.7%
Upper Extremity n=147	0	0	0
Abdomen n=148	2.3%	6.8%	0
Spine n=148	1.2%	0	0
Pelvis n=148	1.2%	6.8%	5.6%
Lower Extremity n=148	2.3%	9.1%	0

Tables 11 and 12 show that whilst frontal oblique impacts are more frequent than perpendicular impacts, the perpendicular impacts result in a more serious MAIS outcome. This is supported by a chi-square test for the occurrence of MAIS 3+ injury (CCIS) ($\chi^2 = 9.055$, d.f.=2, p=0.011). Higher rates of AIS 2+ and AIS 3+ injuries are observed in perpendicular impacts, this being particularly the case for the head, chest, abdomen and pelvis (tables 13 and 14).

The next analysis concerns the collision severity in relation to injury outcome. Delta V is used for this comparison. It should be noted that ***Delta V is a measure of collision severity, not impact speed***. Figure 1 below (CCIS data) shows the cumulative frequency of Delta V according to different injury severity classifications; all MAIS, MAIS 2+ and MAIS 3+. Markers are shown on the graph at the calculated Delta V for a hypothetical struck vehicle with mass 1250kg, for a 50 km/h closing velocity impact with the a 950 kg barrier (mass of current MDB) and a 1500kg barrier.

The Delta V for the hypothetical struck vehicle when the barrier is 950 kg is calculated to be 22 km/h. 80% of the MAIS 2+ and 90% of the MAIS 3+ cases have a higher Delta V. For the 1500kg barrier the struck vehicle the calculated Delta V is 27 km/h; around 70% of the MAIS 2+ cases and 85% of the MAIS 3+ cases have a higher Delta V.

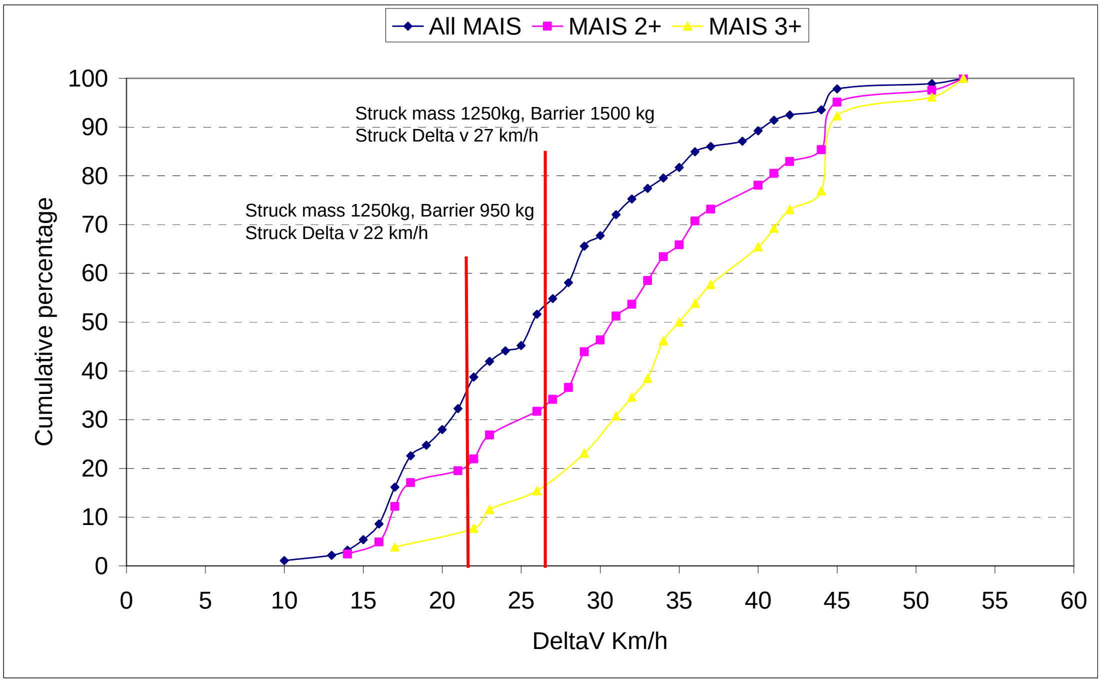

Fig. 1 - Delta V by MAIS - CCIS

Delta V has been banded into 3 groups and the injury rates compared between the different groups for cases with known injury outcome and known delta V (n=93 CCIS, n=54 GIDAS). Tables 15 through 18 explore the relationship between injury outcome and the Delta V groups.

Table 15. MAIS within DeltaV group - CCIS

	Up to 20km/h n=26	21-40 km/h n=57	41-60 km/h n=10*
MAIS 0	11.5%	1.8%	0
MAIS 1	61.6%	53.5%	10.0%
MAIS 2	23.1%	16.1%	0
MAIS 3+	3.8%	28.6%	90%
Total	100%	100%	100%
Fatal	0	8.9%	70.0%

*Percentages should be interpreted with caution due to the low n

Table 16. MAIS within Delta V group - GIDAS

	Up to 20km/h n=42	21-40 km/h n=10*	41-60 km/h N=2*
MAIS 0	52.5%	30.0%	0
MAIS 1	45.0%	50.0%	100%
MAIS 2	2.5%	20.0%	0
MAIS 3+	-	-	-
Total	100%	100%	100%
Fatal			

*Percentages should be interpreted with caution due to the low n

Injury severity (MAIS) increases as the delta V severity banding becomes more severe (tables 15/16). This is supported by a Chi-Square test for the occurrence of MAIS 3+ outcome (CCIS) (χ^2 = 26.448, d.f. =2, p<0.001). Higher rates of AIS 2+ and AIS 3+ head, chest, abdomen and pelvis injury are seen in the higher delta V bands (tables 17/18).

Table 17. Rate of AIS 2+ Injury within DeltaV group - CCIS

	Up to 20km/h	21-40 km/h	41-60 km/h
Head n=91	3.8%	18.2%	70.0%
Chest n=92	3.8%	28.6%	90.0%
Upper Extremity n=91	3.8%	1.8%	40.0%
Abdomen n=92	0	10.7%	50.0%
Spine n=92	0	3.6%	10.0%
Pelvis n=92	11.5%	16.1%	60.0%
Lower Extremity n=92	3.8%	7.1%	30.0%

Table 18. Rate of AIS 3+ Injury within DeltaV Band

	Up to 20km/h	21-40 km/h	41-60 km/h
Head n=91	0	10.9%	70.0%
Chest n=92	0	23.2%	90.0%
Upper Extremity n=91	0	0	0
Abdomen n=92	0	5.4%	20.0%
Spine n=92	0	0	0
Pelvis n=92	0	3.6%	30.0%
Lower Extremity n=92	3.8%	3.6%	20.0%

Whilst in 40% of cases no delta V calculation was possible (62/155) it is suggested that these involved a relatively low delta V where no engagement of the stiff structure occurred therefore invalidating the delta V calculation. These 62 cases also have a lower MAIS distribution than those cases where the delta V was known (70% MAIS 0-1 compared with 54% MASI 0-1). However, the purpose of the analysis has been to identify the speeds at which serious injury occurs and so the conclusions from this section remain valid despite the relatively large amount of missing data.

The next analysis considers the impact location along the side of the vehicle. For this analysis a review was made of the photographic evidence for each case in order to establish the specific location of the impact contact in relation to the A and C pillars of the struck vehicle. The current side impact test states that the positioning of the barrier is such that the centre line of the barrier is aligned with the 'R-point' of the front seat (± 25mm). The proposed change to the test procedure suggests that the centre of the barrier is aligned 250 mm rearwards of the front seat 'R-point'. For the analysis, the cases are categorised according to the location of the damage along the side of the vehicle defined by whether or not the bullet vehicle engaged with either the A pillar, the C pillar, both the A and C pillar or neither the A nor the C pillar (known values for CCIS n=146 and GIDAS n=49). Table 19 shows the MAIS distribution within the damage categories for the CCIS data and table 20 gives the picture for the GIDAS cases.

Table 19. MAIS within damage category - CCIS

MAIS	A and C Pillar both engaged (N=19)	A Pillar but not C Pillar (N=86)	C Pillar but not A Pillar (N=16)	Neither A nor C Pillar (N=25)
0	5.3%	2.3%	12.5%	4.0%
1	57.9%	60.5%	56.2%	56.0%
2	0%	18.6%	6.3%%	24.0%
3+	36.8%	18.6%	25.0%	16.0%
Total	100%	100%	100%	100%
Fatal	15.8%	9.3%	12.5%	8.0%

Table 20. MAIS within damage category – GIDAS

MAIS	A and C Pillar both engaged (N=5)*	A Pillar but not C Pillar (N=19)	C Pillar but not A Pillar (N=7)*	Neither A nor C Pillar (N=18)
0	60%	47.3%	57.1%	44.4%
1	40%	47.3%	28.6%	55.6%
2	0%	5.4%	14.3%	0%
3+	0%	0%	0%	0%
Total	100%	100%	100%	100%
Fatal	0%	0%	0%	0%

*Percentages should be interpreted with caution due to the low n

The MAIS 2+ rate is similar in the CCIS cases across all the damage categories, 30-35%, but the MAIS 3+ rate is highest when both the A and C pillar are contacted. There are however many more cases in the 'A pillar but not C pillar' category compared to the other groups. The GIDAS cases show a higher rate of MAIS 2 injury when the damage starts rear of the A pillar but the number of cases in the group is low. A Chi-Square test for the occurrence of MAIS 3+ outcome (CCIS) is non significant (X^2 = 0.089, d.f. =3, p=0.766). Due to the high p-value in the Chi-Square no further exploration is made of injury outcome in relation to A/C pillar contact.

In this section the AIS 2+ injuries sustained by occupants in the CCIS data are examined. The AIS 2+ injuries have been classified by body region, these being Skull, Brain, Face, Chest Skeletal, Chest Organ, Abdominal Organ, Pelvis, Lower Extremity, Upper Extremity, Spine. Separating the head injuries into skull and brain, and the chest injuries into skeletal and organ, allows for an analysis on an occupant basis to be more clearly understood. Typically AIS 2+ injuries to the other body regions listed are fractures apart from the abdomen where solid organ injury (e.g. to the liver and spleen) predominated. In total, 54 occupants with AIS 2+ injuries are included who, between them, had 197 AIS 2+ injuries.

Figure 2 below shows the distribution of AIS 2+ injuries among the body regions. Each count represents an occupant with at least one AIS 2+ injury to the given body region. Occupants may have sustained more than one AIS 2+ injury in each region but each body region is only counted once per occupant. For MAIS 2+ occupants (54), AIS 2+ injuries are sustained most frequently to the chest, both organ (23/54) and skeletal (21/54), brain injuries (21/54) and pelvic injuries (20/54).

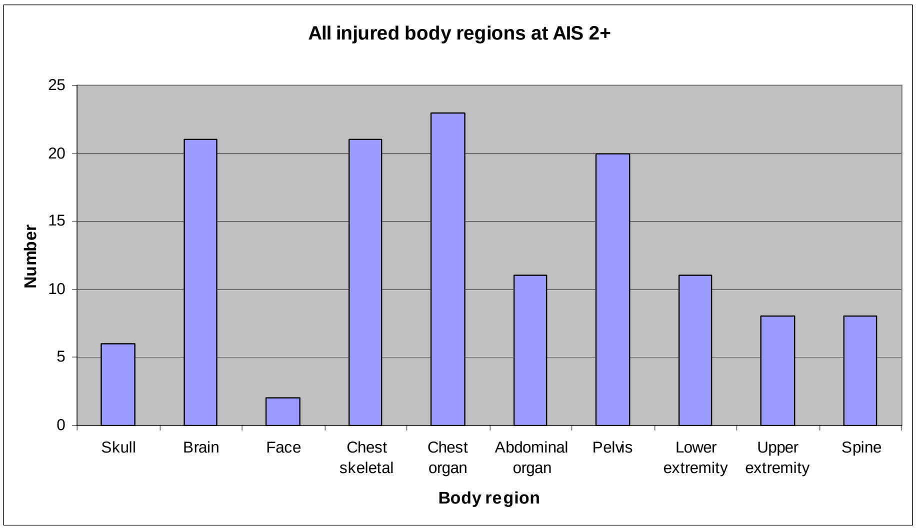

Fig. 2 – AIS2+ injury distribution

Table 21 shows, on an occupant basis, the nature and multiplicity of the AIS 2+ chest injuries and the injury causation codes within the CCIS data. Table 22 repeats this for the head injuries.

Table 21. AIS 2+ chest injuries

	Skeletal only	Organ only	Skeletal and organ
Number of occupants	6	8	15
Causation			
Side door	1	8	13*
Side compartment nfs			1
Seat belt webbing	4		1
External object			1*
Other occupant	1		

*same occupant

Table 22. AIS 2+ head injuries

	Skull only	Brain only	Skull and Brain
Number of occupants	2	17	4
Causation			
External object	1	1	1
Cant rail	1	3	
Side glass		4	1
Side door		1	1
Side compartment nfs		4	
A pillar		2	1
Head restraint		1	
Unknown		1	

The data presented in tables 21 and 22 suggest that chest injuries appear to be a by-product of acceleration applied to the rib-cage and compression of the rib-cage itself leading to damage to the underlying organs since the most common scenario is for rib/thoracic organ injuries to occur together. However, the situation for head injuries is somewhat different since brain injuries were found to occur more commonly in isolation rather than in association with skull fractures.

DISCUSSION

This study has examined the nature and circumstances of side impact crashes with the main aim being to assess the validity of currently proposed changes to the side impact regulatory test procedure. Whilst the study has highlighted benefits in some of the proposed modifications to Regulation 95, for other proposed modifications, the evidence is not so clear-cut.
The findings are described and summarised as follows;

CHANGES TO BARRIER MASS The average mass of bullet or striking vehicles in the data was found to be 1,250kgs which is greater than the mass of the current barrier used in regulatory compliance testing (950kgs). On the surface, this supports the case for increasing the barrier mass by 300kgs or so. However, in this study, no clear relationship was found between bullet vehicle mass and injury outcomes (although higher rates of AIS 2+ and AIS 3+ head and chest injury were observed in occupants of vehicles struck by slightly heavier bullet vehicles). Therefore the case for increasing the barrier mass has not been fully supported in this study.

CHANGES TO BARRIER/VEHICLE CONTACT POINTS In the current regulatory compliance testing procedure, the test protocol determines that the barrier impacts the target in a position that leads to engagement of the both the ‘A’ and ‘C’ pillars (in addition to ‘B’ pillar contact). The proposed change to the test procedure suggests that the centre of the barrier is aligned 250 mm rearwards of the front seat ‘R-point’. The location of damage was examined in the context of this proposed change. 57% of CCIS cases and 41% of GIDAS cases have contact on the A pillar but not the C pillar. These form the largest share considering A/C pillar contact. There is no clear relationship between A/C pillar contact and injury outcome and therefore recommendations for contact points for the barrier cannot be made without further work. In relation to this, whilst oblique impacts (in terms of Direction of Force) were found to occur more frequently in the accident data, higher injury risks were found to occur when the angle of impact was more or less perpendicular. Therefore no changes to the approach angle are recommended.

CHANGES IN CRASH TEST SEVERITY The current regulatory compliance testing procedure stipulates that the impacting test-barrier strikes the subject vehicles at 50km/h. In this study, it was not possible to look at closing speed of the bullet vehicles in real-world side impact crashes although assessment of delta-Vs has been made. There is a clear relationship between injury severity and injury outcome – around 80% of MAIS 2+ injuries occur in impacts with a collision severity (as measured by delta-V) greater than that which occurs in a typical current compliance testing procedure. This supports the case for a higher test-speed in the new regulatory compliance testing procedure although it is not yet clear what this speed should be.

CHANGES TO INJURY CRITERIA USED The data in this study show that the head, chest and pelvis are the main body regions injured at the AIS2+ level in side impacts. Therefore it is appropriate to continue to use injury criteria that predict injury risk to these body regions in the regulatory compliance testing procedures. When looking at AIS2+ injuries, brain injuries were found to occur frequently in isolation (i.e. in the absence of skull fractures) whereas chest organ injuries tend to be associated with rib fractures. Whilst the criteria used to predict chest injury are reasonably representative of the types of injuries that are seen in real-world accidents, the same cannot be said for head injuries and the data reinforce the need for head injury criteria that are not based solely on skull fracture thresholds. However it is suggested that a larger sample and knowledge of the specific thoracic injuries including aspect would be useful first steps to support any recommendation on chest injury criteria.

OTHER OBSERVATIONS In total, only approximately 1 out of every 100 accidents conforms in terms of nature and characteristics of the current regulatory compliance testing procedures. There is no evidence to suggest that this will change if the new procedures are adopted or indeed will improve if the procedures do not change. However, on the basis of the data analysis, there is no one typical condition which characterises the side impact problem and injury outcomes depends on a number of inter-related crash circumstances all of which are impossible to cater for in a single-point testing condition.

It was found that in over half of the cases which were similar to the regulatory compliance testing procedure, an occupant on the ‘struck-side’ of the vehicle was found to be accompanied by an adjacent occupant on the non-struck side. In these cases, the injury rate to the struck-side occupant was found to be higher when the occupant was present on the non-struck side. The new regulatory compliance testing procedure should take this into account and use two crash-test dummies in the frontal seating positions so the effect of occupant-to-occupant interaction can be assessed.

CONCLUSIONS

The mass of the bullet vehicle does not have an effect on the injury distribution but there is a need to consider the benefit of modifying various other aspects of the Regulation 95 test procedure, or to introduce new specifications. These include;

- The impact speed should be increased to better reflect the speeds at which serious injury occurs in struck side impacts;
- However before the appropriate speed can be determined further analysis/testing should be carried out that takes vehicle to vehicle compatibility issues into account;
- The mass of the striking vehicle did not appear to have an effect on the injury outcomes in the struck vehicle. Therefore the case for increasing barrier mass in a new regulatory compliance testing procedure is not supported;

- A perpendicular impacting angle should be used in any future regulatory compliance testing procedures since this condition was found to result in worse injury outcomes when compared to an angled impact configuration;
- Test procedures should be adopted aimed at providing a better assessment of the risk of head injury;
- A further dummy, positioned in the front passenger seat, should be considered in order to assess both occupant interaction effects in side impacts and also to address the protection of non struck side occupants.

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Acknowledgements

This paper uses accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected from 1998 to 2006. CCIS is managed by TRL Limited on behalf of the UK Department for Transport (DfT) Transport Technology and Standards Division who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Daimler-Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe(UK) Ltd have also funded CCIS. The data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham, the Vehicle Safety Research Centre at Loughborough University, TRL Limited and the Vehicle & Operator Services Agency of the DfT. Further information can be found at <http://www.ukccis.org>.