CRASH PERFORMANCE AND OCCUPANT SAFETY IN PASSENGER CARS INVOLVED IN SIDE IMPACTS

B.N. Fildes, and A.P. Vulcan
Monash University Accident Research Centre,
Clayton, Victoria, 3168, Australia.

ABSTRACT

A study was undertaken recently for the Federal Office of Road Safety in Australia examining occupant safety for passengers of current generation automobiles. Mass crash data was analysed and a follow-up investigation of 150 vehicle crashes was undertaken where at least one of the vehicle's occupants was hospitalised. Side impact crashes were of particular interest here. The types of injuries sustained by these occupants (including points of contact within the vehicle) were assessed to provide direction for future improvements in occupant protection. Seat belt performance in all seating positions was also of interest. While the limited number of cases did not permit a full and detailed statistical analysis of these data, the findings neverthe-less show there is scope for improving occupant protection for drivers and passengers of modern passenger cars involved in side impact collisions.

1. INTRODUCTION

In spite of the considerable attention to vehicle occupant safety throughout the world over the last 20 years or so (e.g., design rules for vehicles, impact standards and testing, seat belts, improved vehicle padding, head restraints and door beams) vehicle occupant casualties are still the single largest road safety problem in this country and overseas. Roughly **two** out of **three** persons killed or injured on the road each year in Australia are motor vehicle occupants (Transport and Communications 1988).

Improvements in vehicle crashworthiness historically have tended to focus on frontal crashes. This has been a proper approach, given the high incidence of this crash configuration and the often high impact speeds involved in car-to-car frontal crashes. There has also been growing concern about the relative lack of protection afforded occupants of vehicles involved in side impact collisions (refer discussion in Fildes and Vulcan 1989). This concern is reflected in recent international activity aimed at developing a side impact standard in the USA and in Europe. It is timely then to review the present level of safety for occupants of modern passenger cars involved in side impact collisions to see if it is optimal in this country. In particular, it would be useful to examine the types of injuries and vehicle components involved in these injuries by seating position of the occupant to show the scope for future improvements in side impact occupant protection.

2. RESEARCH STRATEGY

In 1989, a study was undertaken by the Monash University Accident Research Centre for the Federal Office of Road Safety in Australia, aimed at examining the current level of occupant protection in this country. Crash and injury data were collected from two sources. First, the Transport Accident Commission (TAC) in Victoria, the state government's authority responsible for injury compensation for all road trauma victims in this state, maintain comprehensive records on vehicle crashes where an occupant was injured. For crashes involving recent vehicles (post-1981 passenger cars and their derivatives), over 18,000 records were available containing details on circumstances of the crash, number of occupants involved, the injuries sustained, medical, hospital, rehabilitation and compensation costs. These data provide an overall picture of road trauma in Victoria.

Second, to provide additional detailed information on occupant injuries and vehicle component involvement, a study of vehicle crashes that occurred in the Melbourne Metropolitan area and within 1.5hr. drive of the city centre involving a post-1981 passenger car (or derivative) was undertaken. Selection criteria required at least one of the vehicle's occupants to be injured severely enough to require hospitalisation (fatalities prior to hospital were generally not included except when there was also a hospitalised occupant and those who subsequently died in hospital). Hospital patients were interviewed (when possible) as soon as practical after the crash and a detailed inspection was undertaken of the vehicles involved in the crash.

3 METHOD

MASS DATA ANALYSIS - Detailed analyses were performed on the mass data supplied by the Transport Accident Commission on occupants of post-1981 vehicles involved in road crashes between 1982 and 1988. Variables included the age and sex of the occupant, injuries sustained, severity of injury (fatal, hospitalised, non-hospitalised), days in hospital, type of collision, vehicle make and year of manufacture, vehicle weight, drive configuration, etc. These data were further embellished with additional items such as other uninjured occupants, seat belt status, speed zone of the crash, and vehicle model, although a full analysis of these items is not available at this time.

CRASHED VEHICLE STUDY - Three major trauma hospitals in the Melbourne Metropolitan area (The Alfred, Dandenong & District, and Box Hill Hospital) participated in the crashed vehicle study. Whenever a suitable patient was admitted to one of these hospitals, a trained nurse researcher visited the hospital to collect the relevant injury details and interview the patient whenever possible. Patients not wishing to be involved in the study were excluded and confidentiality was strictly maintained. A standard patient information format was developed containing details on the circumstances of the crash, the type of vehicle involved, patient injuries, where the vehicle was taken (if known), and permission to inspect it. Injury severity was assessed from the medical record after the patient had been discharged from hospital based on the 1985 Abbreviated Injury Scale (AIS) manual. Two nurse researchers were thoroughly trained in making these assessments and were shown to be reliable at this task (Ozanne-Smith 1989).

Once the vehicle was located, a mechanical engineer was dispatched to conduct a thorough inspection of it and the other vehicle involved (collisions involving more than two vehicles were generally avoided as in these cases it is often difficult to interpret impact and injury source information unambiguously). Vehicle damage information collected included the damage area, extent of deformation, direction of force (clockface damage scale), detailed lists of components damaged, description of component failures, degree of cabin displacement and deformation, degree of cabin intrusions, signs of contact between components and occupants, apparent use of restraints (head and belts), and any equipment failures or fractures. The engineer had also been trained in conducting vehicle inspections and his inter-rater reliability was judged to be well correlated with another expert (70% agreement).

Crash inspection data were compiled using the National Accident Sampling Survey (NASS) format developed for the National Highway Traffic Safety Administration (NHTSA 1989) with minor changes to suit local conditions. Change of velocity from the impact (delta-V) was computed using the CRASH 3 program (NHTSA 1986) and all data were coded and analysed on the University's VAX computer using SPSSX analysis software (SPSS Inc. 1988). It was only possible to report on the relative occupant safety effects within the sample of vehicles crashed and patients injured (i.e., it was not possible to examine involvement rates within the population at large using these data).

4. RESULTS - MASS DATA

The main source of interest in the results of this study were from the detailed inspection of crashed vehicles. However, the mass data analysis was used to first understand the extent of injury arising from vehicle crashes that occurred in Victoria between 1982 and 1988. Entry into the TAC injury compensation scheme requires that the road trauma claimant exceeded a A$317 (1989 values) threshold of injury treatment and associated costs. Table 1 shows that the proportions of the different crash configurations in this sample were frontals 47%, rear-end crashes 23%, side impacts 25%, and roll-overs 5%. For major injury claimants only (that is, those requiring at least hospitalisation), the equivalent figures were frontals 58%, rear-end 8%, side impact 24%, and roll-overs 9%. Severe injury was over-represented in occupants injured in frontal crashes and rollovers, but under-represented in rear-end crash occupants.

TABLE 1
IMPACT DIRECTION BY OCCUPANT INJURY SEVERITY

IMPACT DIRECTION	FATAL	HOSPITALISATION >6days	HOSPITALISATION <7days	**TOTAL MAJOR INJURY**	MEDICAL TREATMENT ONLY	**TOTAL INJURY**
FRONTAL	245* (186)	938* (737)	1142* (933)	**2325* (1856)**	5551 (6020)	**7876 47%**
REAR IMPACT	7 (95)	115 (374)	216 (473)	**338 (942)**	3661* (3057)	**3999 23%**
SIDE IMPACT	111* (99)	401 (390)	448 (493)	**960 (981)**	3204 (3183)	**4164 25%**
ROLLOVER	37* (21)	129* (82)	198* (104)	**364* (207)**	514 (671)	**878 5%**
TOTAL PATIENTS	**400**	**1583**	**2004**	**3987**	**12930**	**16917**

*Cell entries show the number of injured occupants for each level of injury severity and impact direction. Figures in parenthesis are expected values based on row and column totals, while * shows those which are over-represented (10% or more above the expected value).*

Table 2 shows that drivers comprised 63% of all claimants, front-left passengers 24%, front-centre passengers 0.5%, rear-outboard passengers 10%, and rear-centre passengers 2.5% (it should be noted that vehicles in Australia travel on the left-hand side of the road where drivers sit on the right and front passengers the left side of the vehicle). For major injury claimants, 58% were drivers, 26% front-left, 0.5% front-centre, 13% rear-outboard, and 2.5% rear-centre passengers. There was a tendency for front-left and rear seat passengers to be over-represented in serious injury.

TABLE 2
OCCUPANT SEATING POSITION BY INJURY SEVERITY

BODY REGION INJURED	FATAL	HOSPITALISATION >6days	HOSPITALISATION <7days	**TOTAL MAJOR INJURY**	MEDICAL TREATMENT ONLY	**TOTAL INJURY**
DRIVERS	248 (252)	965 (1020)	1185 (1320)	**2398 (2593)**	8713 (8518)	**11111 63%**
FRONT-CENTRE	2 (1.5)	4 (5.5)	7 (7.5)	**13 (14)**	47 (46)	**60 0.5%**
FRONT-LEFT	89 (96)	433* (389)	566* (504)	**1088* (989)**	3152 (3251)	**4240 24%**
REAR-OUTBOARD	54* (43)	176 (174)	281* (225)	**511* (442)**	1381 (1450)	**1892 10%**
REAR-CENTRE	7 (7)	40* (30)	56* (38)	**103* (75)**	218 (246)	**321 2.5%**
TOTAL PATIENTS	**400**	**1618**	**2095**	**4113**	**13511**	**17624**

*Cell entries show the number of injured occupants for each level of injury severity and seating position. Figures in parenthesis are expected values based on row and column totals, while * shows those which are over-represented (10% or more above the expected value).*

TABLE 3
PROPORTION OF PRINCIPAL INJURIES BY INJURY SEVERITY

BODY REGION INJURED	FATAL	HOSPITALISATION >6days	HOSPITALISATION <7days	**TOTAL MAJOR INJURY**	MEDICAL TREATMENT ONLY	**TOTAL INJURY**
HEAD	40% (49%)	13% (14%)	20% (18%)	**19% (20%)**	6% (9%)	**9% (12%)**
FACE	1% (0%)	1% (3%)	15% (17%)	**11% (9%)**	22% (22%)	**20% (19%)**
NECK: Whiplash	0% (0%)	8% (5%)	15% (13%)	**11% (8%)**	32% (25%)	**27% (20%)**
SPINE: Fracture	4% (3%)	8% (3%)	2% (1%)	**5% (2%)**	1% (0.3%)	**1% (1%)**
SHOULDER	1% (0%)	4% (6%)	3% (5%)	**3% (5%)**	2% (3%)	**2% (4%)**
CHEST	24% (35%)	21% (31%)	19% (24%)	**20% (28%)**	9% (13%)	**12% (17%)**
ABDOMEN	6% (3%)	4% (3%)	3% (3%)	**4% (3%)**	4% (5%)	**4% (4%)**
UPPER LIMB	1% (0%)	6% (7%)	7% (6%)	**6% (5%)**	5% (7%)	**5% (6%)**
LOWER LIMB	1% (0%)	16% (11%)	9% (9%)	**11% (8%)**	8% (11%)	**9% (11%)**
OTHER/UNKNOWN	23% (10%)	10% (18%)	6% (6%)	**9% (11%)**	11% (6%)	**11% (7%)**
TOTAL CRASHES (side impacts)	**422 (63)**	**1696 (214)**	**2162 (233)**	**4280 (510)**	**13907 (1469)**	**18187 (1979)**

Cell entries are the percentage of principal injuries (one injury only per claimant) to occupants in all crash configurations. Those in parenthesis are the proportions of principal injuries from side impacts.

The analysis of principal injuries sustained by vehicle occupants (the most severe injury ascribed by the TAC) for all crash configurations and side impacts only is outlined in Table 3. Major injury cases (where the occupant was either hospitalised or killed in the crash), accounted for 24% of all crash configurations recorded by the TAC, and 26% for side impact crashes. There was very little difference in the rank order of body regions injured between all crash configurations and side impacts, where most injuries occurred in the chest, head, face, lower limb, and the neck. For injuries of all severities, whiplash and minor face injuries were the two most common principal injuries sustained by vehicle occupants.

5. RESULTS - CRASHED VEHICLE STUDY

It was not possible to say anything about the source of injury from the mass data as this information was not available. Hence, the crashed vehicle inspection programme was undertaken for this purpose. To date, information has been collected on 150 crashed vehicles involving 171 injured occupants. There were 69% urban and 31% rural crashes of which details are available on 60 side impact collisions. Even with such relatively small numbers, several important findings were apparent.

TABLE 4
CHARACTERISTICS OF THE CRASHED VEHICLE SAMPLE

CHARACTERISTIC	CRASHED VEHICLE	MASS DATA
1. VELOCITY CHANGE AT IMPACT		
Mean Delta-V	39.2km/h	-
Standard Deviation	21.6km/h	-
2. CRASH TYPE		
Frontal	60%	58%
Side impact	33%	24%
Rear end	0%	8%
Rollover	7%	9%
3. VEHICLE TYPES		
Mini (<750kgm)	5%	2%
Small (751-1000kgm)	26%	41%
Compact (1001-1250kgm)	41%	38%
Intermediates (1251-1500kgm)	23%	16%
Large (>1500kgm)	5%	3%
Mean vehicle weight	1065kgm	1069kgm
4. SEATING POSITION		
Driver	64%	58%
Front-Left	25%	26%
Rear	11%	16%
5. PATIENT SEX		
Males	50%	46%
Females	50%	54%
6. PATIENT AGE		
< 17 years	8%	8%
17 - 25 yrs	27%	21%
26 - 55 yrs	46%	47%
56 - 75 yrs	18%	20%
> 75 years	1%	4%

CHARACTERISTICS OF THE TOTAL SAMPLE - Table 4 shows the characteristics of the total crashed vehicle sample and how it compares with the mass data. Generally, the characteristics were quite similar, except the crashed vehicle sample had a larger proportion of side impact collisions and no rear end crashes. These differences were largely the result of differences in coding procedures and the fact that multiple collisions were excluded from the crashed vehicle study. There was a greater over-involvement of young vehicle occupants in the crashed vehicle sample to the mass data, confirming the tendency for these road users to be over-involved in road crashes. The majority of occupants in the sample survived their collision (only 7% of the patient sample were fatalities).

SIDE IMPACT VEHICLE INTEGRITY - Table 5 lists the rank ordering of component intrusions into the front and rear seat occupant areas for the sample of side impact crashes, where intrusion is defined in relation to the space inside the vehicle likely to be occupied by passengers and normally free of mechanical structures. Most notably, front compartment intrusions were considerably more common than rear compartment intrusions for this population of crashes (5.5 cf. 1.5 intrusions per crash). For front intrusions, the door panel was the most common area of deformation or intrusion, occurring in 47% of all crashes. Steering assemblies were the next most frequent intrusion (31%), followed by the A-pillar (27%), B-pillar (27%), lower side panel (25%), roof side rail (21%), roof (14%), console (8%), floor pan (6%), and front seat (6%).

TABLE 5
RANK ORDERING OF VEHICLE DAMAGE INTRUSIONS FROM SIDE IMPACTS BY FRONT AND REAR SEATING AREAS (52 vehicles)

FRONT COMPARTMENT INTRUSIONS			REAR COMPARTMENT INTRUSIONS		
ITEM	FREQ.	(%)	ITEM	FREQ.	(%)
Door panel	47	(90%)	Door panel	30	(58%)
Steering assy	16	(31%)	Front seat	11	(21%)
A-pillar	14	(27%)	B-pillar	9	(17%)
B-pillar	14	(27%)	Side panel	9	(17%)
Side panel	13	(25%)	Roof side rail	7	(14%)
Roof side rail	11	(21%)	Roof	6	(12%)
Roof	7	(14%)	Window frame	2	(4%)
Console	4	(8%)	W'screen header	1	(2%)
Floor pan	3	(6%)	Floor pan	1	(2%)
Front seat	3	(6%)	Other	2	(4%)
Toe pan	2	(4%)			
Instrument panel	2	(4%)			
W'screen & frame	2	(4%)			
W'screen header	2	(4%)			
C-pillar	1	(2%)			
Other	3	(6%)			
Totals	142	(546%)		79	(152%)

STEERING ASSY MOVEMENTS BY DIRECTION OF DISPLACEMENT

Lateral	7	(14%)
Longitudinal	3	(6%)
Vertical	6	(12%)

Steering assembly intrusions in the top part of the Table refer to cases where there was movement in either a longitudinal, lateral, or vertical plane (movements in more than one plane were only scored as a single movement). The breakdown of intrusions into the total numbers of individual plane movements for all crashes is detailed in the lower part of the Table.

Steering assembly intrusions often comprised multiple intrusions into the driver's occupant space, predominantly involving lateral (14%) and vertical (12%) displacements. Rear compartment intrusions mainly comprise structural deformations to the rear door panel (58%), front seat (21%), B-pillar (17%), 2-door side panel (17%), roof rail (14%), and roof (12%). Importantly, front seat (rearward) deformations or intrusions did account for a sizable 21% of all intrusions into the rear seat occupant space.

SIDE IMPACT BELT WEARING - 90% of all injured occupants involved in side impact crashes wore seat belts at the time of their collision (the overall figure for the total crashed vehicle sample was only 79%). This is similar to on-road wearing rates for Victoria (Vic Roads 1990) perhaps reflecting the absence of protective value for seat belts in side impacts. Almost all belts inspected were retractable and there were no failures of the restraint system observed. Seat belt wearing behaviour was accurately reported by 87% of the occupants interviewed. Of those who gave a different version to that observed during the inspection, almost all claimed to be wearing belts when, in fact, there was no physical evidence of this.

INJURIES & SOURCE OF CONTACT - As noted earlier, this follow-up study was particularly useful in being able to ascribe injury causation from within the vehicle. Side impact collisions were shown to be of sizable magnitude in this crashed vehicle sample (33%) and in the population at large (24%). This section, therefore, will concentrate on injuries and contact sources resulting from this crash configuration. Other publications have described the results of the injury and source contact analysis for other crash configurations (Fildes, Vulcan & Lenard 1990).

Body Regions Injured - The NASS occupant injury classification scheme includes 20 separate body region injury codes. To simplify presentation of the results (especially given the small patient numbers) these were subsequently re-coded into 7 body region categories for analysis, namely head, face, chest, abdomen, upper extremity, lower extremity, and spine. Of particular interest, the abdomen included injuries to the pelvis while the lower limb included all injuries from the hip to the toes.

Table 6 shows that rear seat passengers recorded the highest average number of body regions injured for all severities and crash types at 4.2 per patient, compared to 4.1 for drivers and 3.0 for front seat occupants. Moreover, rear passengers recorded slightly more severe injuries (AIS>2) per patient (1.2), in contrast to drivers (1.1) and front-left passengers (0.9). For all injuries to drivers, the most frequent body regions injured in side impacts were abdomen (90%), chest (70%), head (63%), and upper extremity (63%). For severe injuries only to drivers (AIS>2), the most frequent body regions injured were chest (47%), abdomen (30%), head (17%), and lower extremity (10%). There were no severe injuries to the spine for these occupants.

For front-left passengers, the most frequent injuries were in the chest (71%), head (65%), abdomen (65%), face (35%), and lower extremity (35%), while for severe injuries, the most frequent injuries were the chest (35%), abdomen (35%), and head (12%). There were no severe injuries to the face or lower extremities of the front-left seat passengers. For rear seat passengers, the most frequent body regions injured comprised the chest (77%), face (69%), upper extremity (69%), abdomen (62%), and head (54%), while for severe injuries only, the order of most frequent body region injured was the chest (46%), abdomen (38%), head (31%), and upper extremity (8%). There were no severe face, lower extremities, or spine injuries in this seating position.

TABLE 6
BODY REGION INJURED BY SEATING POSITION FOR OCCUPANTS INVOLVED IN SIDE IMPACT COLLISIONS

BODY REGION INJURED	DRIVERS (n=30) ALL (AIS>2)	FRONT LEFT (n=17) ALL (AIS>2)	REAR (n=13) ALL (AIS>2)
Head	63% (17%)	65% (12%)	54% (31%)
Face	40% (3%)	35% (0%)	69% (0%)
Chest	70% (47%)	71% (35%)	77% (46%)
Abdomen	90% (30%)	65% (35%)	62% (38%)
Upper extremity	63% (7%)	24% (6%)	69% (8%)
Lower extremity	40% (10%)	35% (0%)	46% (0%)
Spine	30% (0%)	6% (6%)	38% (0%)
Average/Patient	**4.0 (1.1)**	**3.0 (0.9)**	**4.2 (1.2)**

Figures for ALL INJURIES show the percentage of patients who had at least 1 injury in that particular body region (of any level of severity). Figures in parenthesis show the percentages for severe injuries only (AIS>2). Averages per patient are the mean number of total and the mean number of severe body regions injured recorded per patient.

Vehicle Contacts - The NASS injury source classification further allows for scoring 82 specific vehicle components as points of contact. Again, to simplify presentation of the results for this limited number of cases, these were collapsed into 13 vehicle regions, comprising windscreen and header, steering wheel, steering column, instrument panel, console, pillars, side glazing (window and door frame), interior surface (roof, side rail and door panel), seats, seat belts, other occupants, floor, and other/unknown. Steering column included pedal contacts, floor consisted of floor and toe pan in the front, instrument panel comprised both upper and lower sections, while side glazing combined contacts to the glass as well as the door frame. Table 7 shows the points of contact by seating position for all and severe injuries.

TABLE 7
POINTS OF CONTACT BY SEATING POSITION FOR OCCUPANTS INVOLVED IN SIDE IMPACT COLLISIONS

POINTS OF CONTACT	DRIVERS (n=30) ALL (AIS>2)	FRONT LEFT (n=17) ALL (AIS>2)	REAR (n=13) ALL (AIS>2)
W'screen & header	0% (0%)	6% (6%)	0% (0%)
Steering wheel	17% (0%)	0% (0%)	0% (0%)
Steering column	3% (0%)	0% (0%)	0% (0%)
Instrument panel	33% (7%)	18% (6%)	0% (0%)
Console	13% (0%)	0% (0%)	0% (0%)
Pillars	7% (7%)	24% (6%)	9% (9%)
Side Glazing	10% (0%)	18% (0%)	18% (9%)
Interior surfaces	67% (57%)	82% (47%)	64% (36%)
Seats	7% (0%)	0% (0%)	18% (0%)
Seat belts	50% (7%)	47% (0%)	18% (0%)
Other occupants	10% (7%)	0% (0%)	9% (0%)
Floor & toe pan	7% (3%)	0% (0%)	9% (0%)
Average/patient	**2.9 (0.9)**	**2.4 (0.8)**	**1.6 (0.7)**

Figures for ALL CONTACTS show the percentage of patients who had at least 1 contact injury of any severity. Figures in parenthesis show the percentages for severe injuries only (AIS>2), while averages per patient show the mean number of contacts per patient for all and severe injuries only.

For all occupant injuries and collision types, the most frequent points of contact for drivers were the interior surface (67%), seat belts (50%), instrument panel (33%), steering wheel (17%), side glazing (10%), and other occupants (10%). For severe driver injuries, the most frequent point of contact was the interior surface (57%). The most frequent points of contact for front-left passengers included interior surfaces (82%), seat belts (47%), pillars (24%), instrument panel (18%), and side glazing (18%), while severe injury contacts for these occupants were again essentially confined to contact with interior surfaces (47%). For rear seat passengers, the frequent contact points comprised interior surfaces (64%), seats (18%), seat belts (18%), and the side glazing (18%). The only noteworthy severe rear seat injury contact was interior surfaces (36%).

Injury & Source Interactions -It should be noted that when comparing body regions injured with their points of contact, multiple injuries and/or contact sources were allowed for each patient when there were unique combinations (i.e., 2 head injuries, one from the steering wheel and another from the dashboard), but only the most severe injury/source contact was allowed for similar combinations (i.e., 2 head injuries to a patient from the steering wheel). This was to ensure that all unique body regions injured or points of contact were included in the analysis.

Drivers- Table 8 shows the injury/source contact percentages per patient (for all injuries and for severe injuries (AIS>2) only) for the 30 drivers hospitalised from side impact crashes. The most noteworthy all severity injury/source combinations were:

- abdomens with interior surfaces (50%),
- abdomens with seat belts (47%),
- chest with interior surfaces (40%),
- upper extremity with interior surfaces (33%),
- lower extremity with instrument panel (23%),
- spine with interior surfaces (20%),
- chest with seat belt (20%), and
- upper extremity with seat belt (20%).

For severe injuries only to drivers, the most noteworthy injury/source combinations comprised:

- chest with interior surfaces (33%),
- abdomens with interior surfaces (23%),
- head with pillar (7%),
- upper extremity with interior surface (7%), and
- chest with other occupant (7%).

Front-Left Passengers - Table 9 shows the injuries and points of contact for the 16 hospitalised front-left seat passengers for all injuries and for severe injuries only. For injuries of all severities, the most noteworthy injury/source combinations were:

- abdomen with interior surfaces (50%),
- chest with interior surfaces (50%),
- chest with seat belt (38%),
- lower extremity with interior surface (31%), and
- abdomen with seat belt (25%).

For severe injuries only to front-left passengers, there were only 2 noteworthy injury/source combinations, namely chest with interior surface (25%), and abdomen with interior surface (25%).

TABLE 8
BODY REGION INJURIES BY POINT OF CONTACT FOR 30 DRIVERS INJURED FROM SIDE IMPACT COLLISIONS.

	HEAD	FACE	CHEST	ABDOMEN	UPPEXT	LOWEREXT	SPINE	TOTAL
WS/HEADER	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER WHEEL	3% (0%)	3% (0%)	3% (0%)	7% (0%)	7% (0%)	0% (0%)	0% (0%)	23% (0%)
STEER COLUMN	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	3% (0%)	0% (0%)	3% (0%)
INSTRU. PANEL	0% (0%)	0% (0%)	0% (0%)	7% (3%)	7% (0%)	23% (3%)	0% (0%)	37% (7%)
CONSOLE	0% (0%)	0% (0%)	0% (0%)	13% (0%)	0% (0%)	0% (0%)	0% (0%)	13% (0%)
PILLARS	7% (7%)	7% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	13% (7%)
SIDE GLAZE	10% (0%)	7% (0%)	0% (0%)	0% (0%)	7% (0%)	0% (0%)	0% (0%)	23% (0%)
INTERIOR SURF	13% (3%)	3% (0%)	40% (33%)	50% (23%)	33% (7%)	13% (3%)	20% (0%)	173% (70%)
SEATS	7% (0%)	0% (0%)	3% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	10% (0%)
BELTS	0% (0%)	0% (0%)	20% (3%)	47% (3%)	20% (0%)	0% (0%)	0% (0%)	87% (7%)
OTH.OCCU.	7% (3%)	7% (3%)	10% (7%)	7% (0%)	3% (0%)	0% (0%)	0% (0%)	33% (13%)
FLOOR	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	7% (3%)	0% (0%)	7% (3%)
OTH.UNK.	23% (0%)	23% (0%)	3% (3%)	10% (0%)	23% (0%)	3% (0%)	10% (0%)	97% (3%)
TOTAL	70% (13%)	50% (3%)	80% (47%)	140% (30%)	100% (7%)	50% (10%)	30% (0%)	520% (110%)

The figures on the top row show the percentage of total patients who sustained a particular injury by source combination for injuries of all severities. Those in parenthesis show the injury by source rates for severe (AIS > 2) injuries only.

TABLE 9
BODY REGION INJURIES BY POINT OF CONTACT FOR
17 FRONT LEFT PASSENGERS INJURED FROM SIDE IMPACT COLLISIONS.

	HEAD	FACE	CHEST	ABDOMEN	UPPEXT	LOWEREXT	SPINE	TOTAL
WS/HEADER	6% (6%)	6% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	12% (6%)
STEER WHEEL	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER COLUMN	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
INSTRU. PANEL	0% (0%)	0% (0%)	6% (6%)	0% (0%)	0% (0%)	18% (0%)	0% (0%)	24% (8%)
CONSOLE	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
PILLARS	12% (6%)	6% (0%)	6% (0%)	0% (0%)	6% (0%)	0% (0%)	0% (0%)	29% (6%)
SIDE GLAZE	18% (0%)	12% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	29% (0%)
INTERIOR SURF	0% (0%)	6% (0%)	53% (29%)	53% (29%)	18% (8%)	29% (0%)	6% (6%)	165% (71%)
SEATS	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
BELTS	0% (0%)	0% (0%)	35% (0%)	24% (0%)	0% (0%)	0% (0%)	0% (0%)	59% (0%)
OTH.OCCU.	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
FLOOR	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
OTH.UNK.	29% (0%)	12% (0%)	18% (12%)	12% (6%)	6% (0%)	0% (0%)	0% (0%)	76% (18%)
TOTAL	65% (12%)	41% (0%)	118% (47%)	88% (35%)	29% (6%)	47% (0%)	6% (6%)	394% (106%)

The figures on the top row show the percentage of the total patients who sustained a particular injury by source combination for injuries of all severities. Those in parenthesis show the injury by source rates for severe (AIS > 2) injuries only.

Rear Seat Passengers - Table 10 shows the injury/source combinations for the 11 hospitalised rear seat passengers (all and severe injuries) where the 3 most noteworthy included:

. chest with interior surface (46%),
. abdomen with interior surface (36%), and
. upper extremity with interior surface (36%).

For severe injuries, the most noteworthy injury/source combinations were:

. chest with interior surfaces (27%),
. abdomens with interior surfaces (18%),
. head with pillar (9%), and
. head with side glazing (9%).

As the seat belt wearing rates were especially high amongst these injured occupants, there was little to be gained in analysing the injuries and points of contact by belt wearers and non-wearers.

Near and Far Collisions - The final analysis undertaken was an attempt to examine whether injuries and points of contact were different for occupants seated on the impacted side (NEAR) as opposed to the opposite side (FAR). Previous evidence suggested that there would be substantial differences here (Dalmotas 1983; Otte et al 1984; Rouhana and Foster 1985). It was only possible to examine near and far differences for drivers, given the small number of cases currently available and the relative lack of front-left and rear passengers hospitalised after far-side impact crashes (2:17 and 1:11 respectively).

Table 11 shows that for the 19 drivers involved in near side impact crashes, the most frequent injuries (all severities) occurred in the abdomen (142%), upper extremity (105%), chest (84%), head (68%), and lower extremity (60%). Common points of contact included interior surfaces (242%), seat belts (47%), side glazing (37%), steering wheel (26%), and instrument panel (26%). The noteworthy injury/source contacts were:

. abdomens with interior surfaces (74%),
. chest with interior surfaces (60%),
. upper extremity with interior surfaces (47%),
. abdomens with seat belts (32%),
. spine with interior surfaces (26%), and
. lower extremity with interior surfaces (21%).

For severe injuries (AIS>2) to drivers in near-side impacts, the most notable body regions injured were the chest (53%), abdomen (37%), head (11%), and lower extremity (11%). There were no major injuries recorded for the face or spine amongst these occupants. The only points of contact were interior surfaces - roofs and doors (95%), pillars (11%), and floor (5%). The 3 most noteworthy injury/source contacts were:

. chest with interior surfaces (47%),
. abdomens with interior surfaces (37%), and
. head with pillar (11%).

Table 12 shows the injury/source analysis for the 11 drivers involved in side impacts when seated on the far side. There was no marked difference in the frequency of body regions injured over that for near side drivers. However, the relative frequency of the points of contact was different, including seat belts (155%), other occupants (91%), interior surfaces

TABLE 10
BODY REGION INJURIES BY POINT OF CONTACT FOR
11 REAR SEAT PASSENGERS INJURED FROM SIDE IMPACT COLLISIONS.

	HEAD	FACE	CHEST	ABDOMEN	UPPEXT	LOWEREXT	SPINE	TOTAL
WS/HEADER	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER WHEEL	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER COLUMN	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
INSTRU. PANEL	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
CONSOLE	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
PILLARS	9% (9%)	9% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	18% (9%)
SIDE GLAZE	18% (9%)	18% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	36% (9%)
INTERIOR SURF	0% (0%)	18% (0%)	45% (27%)	36% (18%)	36% (0%)	18% (0%)	9% (0%)	164% (45%)
SEATS	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	18% (0%)	0% (0%)	18% (0%)
BELTS	0% (0%)	0% (0%)	9% (0%)	0% (0%)	9% (0%)	0% (0%)	0% (0%)	18% (0%)
OTH.OCCU.	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
FLOOR	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	9% (0%)	0% (0%)	9% (0%)
OTH.UNK.	18% (0%)	18% (0%)	18% (9%)	18% (9%)	18% (9%)	18% (0%)	18% (0%)	127% (27%)
TOTAL	45% (18%)	64% (0%)	73% (36%)	55% (27%)	64% (9%)	64% (0%)	27% (0%)	391% (91%)

The figures on the top row show the percentage of the total patients who sustained a particular injury by source combination for injuries of all severities. Those in parenthesis show the injury by source rates for severe (AIS > 2) injuries only.

TABLE 11
BODY REGION INJURIES BY POINT OF CONTACT FOR
19 DRIVERS INJURED FROM "NEAR" SIDE IMPACT COLLISIONS.

	HEAD	FACE	CHEST	ABDOMEN	UPPEXT	LOWEREXT	SPINE	TOTAL
WS/HEADER	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER WHEEL	0% (0%)	0% (0%)	5% (0%)	11% (0%)	11% (0%)	0% (0%)	0% (0%)	26% (0%)
STEER COLUMN	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	5% (0%)	0% (0%)	5% (0%)
INSTRU. PANEL	0% (0%)	0% (0%)	0% (0%)	5% (0%)	5% (0%)	16% (0%)	0% (0%)	26% (0%)
CONSOLE	0% (0%)	0% (0%)	0% (0%)	11% (0%)	0% (0%)	0% (0%)	0% (0%)	11% (0%)
PILLARS	11% (11%)	11% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	21% (11%)
SIDE GLAZE	16% (0%)	11% (0%)	0% (0%)	0% (0%)	11% (0%)	0% (0%)	0% (0%)	37% (0%)
INTERIOR SURF	16% (0%)	0% (0%)	58% (47%)	74% (37%)	47% (5%)	21% (5%)	26% (0%)	242% (95%)
SEATS	5% (0%)	0% (0%)	5% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	11% (0%)
BELTS	0% (0%)	0% (0%)	11% (0%)	32% (0%)	5% (0%)	0% (0%)	0% (0%)	47% (0%)
OTH.OCCU.	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
FLOOR	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	11% (5%)	0% (0%)	11% (5%)
OTH.UNK.	21% (0%)	21% (0%)	5% (5%)	11% (0%)	26% (0%)	5% (0%)	0% (0%)	89% (5%)
TOTAL	68% (11%)	42% (0%)	84% (53%)	142% (37%)	105% (5%)	58% (11%)	26% (0%)	526% (116%)

The figures on the top row show the percentage of the total patients who sustained a particular injury by source combination for injuries of all severities. Those in parenthesis show the injury by source rates for severe (AIS > 2) injuries only.

TABLE 12
BODY REGION INJURIES BY POINT OF CONTACT FOR
11 DRIVERS INJURED FROM "FAR" SIDE IMPACT COLLISIONS.

	HEAD	FACE	CHEST	ABDOMEN	UPPEXT	LOWEREXT	SPINE	TOTAL
WS/HEADER	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
STEER WHEEL	9% (0%)	9% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	18% (0%)
STEER COLUMN	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
INSTRU. PANEL	0% (0%)	0% (0%)	0% (0%)	9% (9%)	9% (0%)	36% (9%)	0% (0%)	55% (18%)
CONSOLE	0% (0%)	0% (0%)	0% (0%)	18% (0%)	0% (0%)	0% (0%)	0% (0%)	18% (0%)
PILLARS	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
SIDE GLAZE	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
INTERIOR SURF	9% (9%)	9% (0%)	9% (9%)	9% (0%)	9% (9%)	0% (0%)	9% (0%)	55% (27%)
SEATS	9% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	9% (0%)
BELTS	0% (0%)	0% (0%)	36% (9%)	73% (9%)	45% (0%)	0% (0%)	0% (0%)	155% (18%)
OTH.OCCU.	18% (9%)	18% (9%)	27% (18%)	18% (0%)	9% (0%)	0% (0%)	0% (0%)	91% (36%)
FLOOR	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)
OTH.UNK.	27% (0%)	27% (0%)	0% (0%)	9% (0%)	18% (0%)	0% (0%)	27% (0%)	109% (0%)
TOTAL	73% (18%)	64% (9%)	73% (36%)	136% (18%)	91% (9%)	36% (9%)	36% (0%)	509% (100%)

The figures on the top row show the percentage of the total patients who sustained a particular injury by source combination for injuries of all severities. Those in parenthesis show the injury by source rates for severe (AIS > 2) injuries only.

(55%), and the instrument panel (55%). The most important injury/source combinations were:

- . abdomen with seat belt (73%),
- . upper extremity with seat belt (46%),
- . chest with seat belt (36%),
- . lower extremity with instrument panel (36%), and
- . chest with other occupants (27%).

For severe injuries to drivers in far-side impacts, the most notable body regions injured were the chest (36%), abdomen (18%), and head (18%). Once again, there were no major injuries recorded to the spine. The only substantial points of contact included other occupants (36%), interior surfaces (27%), seat belts (18%), and the instrument panel (18%). The only noteworthy major injury/source contact was chest with other occupant (18%).

6. DISCUSSION

The mass data analysis showed that in severe crashes (those involving a hospital or fatal outcome), vehicle occupants sustained considerable numbers of severe injuries to the chest, head, face, lower and upper extremities and the neck from vehicle crashes in Victoria between 1982 and 1988. Moreover, the proportion injury rankings did not differ substantially for side impacts over all crash types. Collectively, principal injuries to the head, chest and abdomen accounted for approximately three-quarters of all vehicle occupant road deaths (including those from side impacts) during this period. While seat belt wearing status was not available for these data at this time, it should be noted that seat belt wearing in Victoria has been consistently high in the front seat (94%), although lower in the rear (66%), during this time period (Vic Roads 1990).

A follow-up study of crashed vehicles where at least one occupant sustained hospitalisation injuries was undertaken to examine these injury patterns further and demonstrate what components within the vehicle were commonly associated with these injuries. While the follow-up study examined all crash configurations that occurred during the study period, side impact collisions were of particular interest here. It should be noted that there were differences in the proportions of crashes, vehicles and patients in the crashed vehicle sample over that from the mass data (these were outlined in the result section). In particular, lower seat belt wearing rates were observed for both front and rear seat occupants for all crash configurations in this study over those reported for the motoring population, although these differences were less apparent for side impacts. These differences are consistent with the fact that seat belts provide protection in crashes (especially front impacts) and possibly that those who do not wear seat belts may be more likely to be involved in a crash.

BODY REGION INJURIES - For the side impact crashes inspected in this study, there was a tendency for rear seat passengers and drivers to have more body regions injured than did front-left passengers. However, there did not appear to be any particular seating position bias in the average number of severe injuries per patient. It should be stressed that these findings might be influenced somewhat by the fact that occupants had to be hospitalised to be included in the study (a severe injury was probably a pre-requisite to being admitted to hospital).

The <u>types</u> of injuries sustained did appear to differ across the three seating positions. There was a higher likelihood of a head and face injury for rear seat occupants than front seat occupants, although drivers had a slightly higher risk of a severe head injury than front-left passengers. All positions, though, seemed equally vulnerable to injuries (major and severe) to the chest. Abdominal injuries were more apparent for drivers than either front-left or rear seat passengers which may have been a function of the disproportionate number of far-side impacted drivers injured in this sample (this crash configuration resulted in injury almost every time to the abdomen from the seat belt). However, it should be noted that there was practically no difference in severe abdominal injuries across all seating positions. Severe lower extremity injuries were more prevalent amongst drivers suggesting that these occupants may have a particular problem with the steering assembly and foot pedals. Front-left passengers had far fewer minor (but more severe) spinal injuries than either rear seat passengers or drivers. In short, there did not appear to be any injury advantage for rear seat occupants over front seat occupants for the side impact crashes inspected in this study.

These injury findings were similar to those observed in the mass data. Other researchers have also reported severe injuries to the chest, abdomen, and head/neck regions of the body by the driver and front passenger in the USA (Rouhana and Foster, 1985) and the UK (Jones 1982), or for front occupants in Germany (Otte et al, 1984). Dalmotas (1983) found that head and face injuries were marginally more common than chest and abdomen/pelvis injuries for his sample of 98 side impact crashes in Canada during the 1970's. While there may be slight differences in the order of body region involvement across these studies, clearly these body regions are most at risk of severe injuries from side impact crashes. Interestingly, there were very few differences in order or magnitude of body regions injured by whether the driver was positioned on the near- or far-side of the impacted vehicle, either here or in all of the other studies noted above. The greatest effect on occupant injuries from the near and far relationship in side impact collisions appears to be in which vehicle component actually caused the injury. This will be discussed more fully in the next section.

There was a difference in the percentage of severe seat belt injuries between drivers and front-left passengers (10% cf. 2%). This is a little surprising as they had similar seat belt wearing rates overall. In addition, the analysis for frontal crashes reported in Fildes, Vulcan and Lenard (1990) shows a similar, albeit more moderate difference (15% cf. 5%), in seat belt contacts for belted occupants in these two seating positions, suggesting that this anomaly is not a function of different crash configurations. It might be related to age and sex differences between occupants in these two seating positions or to minor differences in the coding of contact points between these two seating positions where a few seat belt contacts for drivers may have actually been the result of contact with some other component (e.g., the steering wheel). Further analysis is warranted here when there are more cases available.

POINTS OF CONTACT - The most common vehicle components associated with injuries to front seat occupants included interior surfaces (roofs and doors), seat belts, the steering wheel (for drivers), instrument panels, and windscreen and headers. In terms of severe injury contacts, interior surfaces, the steering wheel, and the instrument panel were particularly involved. As noted above, the points of contact for the drivers' injuries varied depending upon whether they were seated on the near or far side of the impacted vehicle. In near side impacts, the interior surfaces (mainly door panels and hardware) predominated in association with these injuries, while for far side impacts, the seat belt and other occupants were the major source of injury. This was the case for all severities of injury examined here. The steering wheel seemed to be a problem for drivers' heads and faces in far-side crashes and their chests, abdomens, and upper extremities in near-side impacts, although only involving minor injuries. For rear seat passengers, interior surfaces and side glazing (including the window frame) were the only noteworthy contact points.

The results are remarkably similar to those reported for drivers by Jones (1982), Dalmotas (1983), and Rouhana and Foster (1985). They found interior surfaces to be the common cause of severe injuries to both drivers and front seat passengers when involved in near-side crashes, which was not appreciably influenced by whether the occupant was restrained or not. Most of these authors also reported a greater involvement in occupant injuries from the steering system, instrument panel, and glovebox and a lesser involvement in seat belt injuries than was observed here. This was most likely a function of the low belt wearing rates in these earlier studies, compared to that experienced here. Otte et al (1984), too, reported over-involvement of the door and its hardware in front seat occupant injuries in near-side impacts and a sizable number of seat belt injuries to the abdomen for those who were wearing belts. Unfortunately, though, they did not differentiate between driver and front seat passenger contacts.

INJURIES AND CONTACTS - The results of the injury/source contact analysis of those involved in side impacts casts further light on the relationship between occupant injuries and the points of contact inside the vehicle. For drivers in near-side impacts, interior surfaces resulted in injuries to the abdomen, chest and upper extremity in that order. This demonstrates the need to emphasise occupant protection in the lower region of the vehicle side. When severe injuries are considered, there appears to be a case for treating the inside of the B-pillar. For drivers in far-side crashes, there was an abnormally high rate of seat belt injuries to the abdomen and upper extremities of the body. This suggests the need for better lateral support in seat design (and maybe further improvements in seat belt geometry) to protect these occupants.

For rear seat passengers, chest and abdomens again featured highly in contacts with interior door surfaces, showing that there is a need for improved strengthening and better internal padding of both front and rear doors. Head injuries from contacts with B-pillars and side glazing (door frame) was of some concern for these rear seat occupants and is evidence of the need for more attention to improved internal padding in these regions. It was not possible to assess whether seat belt wearing in the rear seat or the side of impact markedly influenced this pattern of results because of the small amount of data available in the database at this time.

VEHICLE INTEGRITY - The findings for vehicle integrity show that structural deformation or intrusion was quite common amongst the vehicles inspected (particularly in the front seat areas but also of sizable proportions in the rear regions as well). Floor, roof and door panels were common offenders although the more structural members (pillars, instrument panels, side rails, etc.) were also frequently distorted in these crashes. Steering assembly intrusions rated highly in the front seat (28% in all crashes), comprising lateral, longitudinal, and vertical movements. While current standards are aimed at reducing longitudinal movement only, the fact that there were severe injury contacts between the occupants and the wheel in the longitudinal, vertical or lateral distorted position, suggests that this standard may not be totally adequate in preventing occupant injuries.

7. CONCLUSION

In summary, occupants of vehicles involved in side impacts sustained a high proportion of injuries to the chest, abdomen, head, and upper extremity from contacts with interior surfaces (roofs and doors), seat belts, the instrument panel, steering assemblies (for the driver), and door frame and perhaps side glazing and pillars for rear seat passengers. "Near" side impacts were over-involved in these cases, although a sizable number of drivers also sustained hospitalised injuries from "far" side impacts (especially involving contacts with the seat belt and instrument panel). Drivers and rear seat passengers experienced more injuries from side impacts than those in the front-left seating position. It is somewhat surprising that while head injury ranked highly as a body region injured, it was only identified as an important injury/source contact in the rear seating position. This may have been, in part, a function of the relatively large number of head injuries where a point of contact could not be identified.

While there is clearly a need for more data to be collected to firmly establish the patterns observed here, the trends so far indicate there is considerable scope for further reducing the number and severity of occupant injuries from contacts within the vehicle in side impact collisions. Apart from structural improvements, more effective restraint systems, more forgiving (padded) door panels and instrument panels, better lateral support in seat design, and improved protection from B-pillar and roof side rail (especially in the rear occupant areas) are all likely to be successful countermeasures against many of these injuries. Their cost effectiveness, however, still needs to be firmly established for Australian road users.

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