Australia's National Crash In-Depth Study
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Abstract

Australia's National Crash In Depth Study has been running for more than two years, with over 200 cases collected to date in Victoria and NSW. Participants of this retrospective study have been hospitalised as a result of injuries sustained in a motor vehicle crash, where the vehicle in which they were travelling is no older than 10 years. Data relating to the participant's recall of crash events is collected via a structured interview, their medical records examined, their vehicle inspected and photographed and the crash scene inspected in detail. A 'best evidence synthesis' approach (Slavin, 1986) is utilised to determine the crash circumstances, occupant injury causation and potential contributing factors to the crash.

The case vehicles in the study comprise 48% 'Large' cars and 4WDs (or SUVs) and 39% 'Small' cars, demonstrating the current polarisation of the vehicle market. Over 80% of the objects struck were other cars or trees and poles. Delta-V, an indication of crash severity, was more than 50% higher for rural compared with urban crashes. With respect to injuries, cases with injuries of MAIS2 or greater, chest and lower extremity injuries predominate for car-car crashes, while head, chest and injuries to the extremities were the most common for car-pole crashes. Information relating to the road environment is presented.

ANCIS is unique in that study sponsors from such varied backgrounds as the automobile industry, state and federal governments, automobile clubs and road designers are successfully collaborating. This study is important for Australia by offering a more detailed set of vehicle crash data for analysis and intervention than is presently available in mass data. The study highlights that motor vehicle crashes are not only a function of the car and its occupants, but also the road environment and infrastructure play an integral role in both injury causation and outcome.

Introduction

Australia's National Crash In-Depth Study has been running for over two years, with over 200 cases collected to date in Victoria and NSW. Participants are admitted to the study while in hospital as a result of injuries sustained in a motor vehicle crash. The vehicle in which they were travelling must be no older than ten years since manufacture. A structured interview is conducted with the participant, where able, their medical records are examined to accurately determine their injuries and the crashed vehicle located to be photographed and examined in detail. The crash scene is generally visited within a few days of the crash and the police report obtained. Where possible, any other vehicles that collided with the case vehicle are also photographed and measured for a more accurate estimate of crash severity. At the conclusion of the data collection process, a multi-disciplinary group uses a best evidence synthesis approach to determine crash circumstances, injury causation and attempts to identify any obvious contributing factors to the crash. The case is then entered into a database, without any personally identifying details. Sufficient cases have been collected that it is now possible to report on some of the trends observed regarding vehicle and impact type, occupant injuries and the road environment where the crashes occurred.

Method

The data collection method documented in Shields *et al* (2001) is still being applied in principle, however the experience gained through two years of collecting cases has allowed the process to be refined and information relating to the crash scene added. The method is summarised below:

1. The potential participant is identified by a Research Nurse in one of the thirteen hospitals currently participating in Victoria and NSW.
2. Once permission has been given by hospital staff to approach the person, the age of the vehicle in which they were travelling is determined and the appropriate consent forms signed. Consent is obtained from a parent, legal guardian or next-of-kin where the participant is a minor or comatose. Of the participants approached, only 14% are admitted to the study, with the most common rejection criterion being vehicle age. A structured interview is then conducted with participants that are able to do so, covering human, vehicle and road environment factors, both pre- and post-crash.
3. The participant's medical records are consulted and all verified injuries documented and coded in accordance with the Abbreviated Injury Scale (AIS) (AAAM, 1998). The Maximum Abbreviated Injury Score (MAIS) and Injury Severity Score (ISS)[2] are also determined.

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4. The Vehicle Coordinator locates the case vehicle and a Vehicle Inspector comprehensively measures and inspects the vehicle. Comprehensive digital photographs are made of the entire inspection. An estimate of crash severity is made in the form of case vehicle velocity change, 'delta-V' and Equivalent Barrier Speed (EBS) using CRASH3 reconstruction software.
5. The Scene Inspector visits the crash scene to take photographs of the scene from the perspectives of all crash participants. Road and environment characteristics such as posted speed limits, line markings, traffic signs and signals and topology are recorded. Any remaining evidence of the crash is also noted.
6. The team meet to resolve the contact sources for each of the injuries, which are then coded using both ICC and NASS systems. They also draw conclusions regarding the crash circumstances using a 'best evidence synthesis' approach. The case is also checked by a broader Case Review Panel.
7. The Case Coordinator prepares a summary sheet containing all pertinent features of the case and checks the entire case for consistency and identifies and corrects any errors.
8. Completed cases are deidentified and entered into a database.

The multi-disciplinary collaborative approach and rigorous checking process ensure that cases are of high quality and the resulting database able to be relied upon to yield consistent analyses.

The growing pool of completed cases may be used in two main ways: (a) individual cases can be used to study examples of specific impact types, injury outcomes or road environment situations or; (b) mass data analyses carried out to identify trends or correlations within the extensive list of variables. The results that will be presented in the following sections form a small subset of the depth of information that can be extracted from such a database. Furthermore, as the number of cases increases more complex or specific analyses will become possible.

Data Analysis

Descriptive data such as group means and percentages are presented. Test of significance, where relevant, include 1-way ANOVA's, t-tests, and logistic regression. Logistic regression was used to examine differences between the risk of sustaining MAIS 2+ injuries between occupants in car-car and car-pole crashes, while correcting for impact severity (Equivalent Barrier Speed, EBS). Analysis was conducted using SPSS v.10 and Stata v.7 Intercooled.

Results

As at September 2002, a total of 208 occupants in Victoria and 15 occupants in NSW have been recruited to ANCIS. This paper discusses the first 170 completed cases to date; four of whom were recruited from NSW hospitals.

Figure 1 shows the distribution of case vehicles by manufacturer. Figure 1 indicates that Holden (n=46; 27%), Ford (n=25; 15%), Mitsubishi (n=24; 14%) and Toyota (n=20; 12%) represent the majority of case vehicles. Other manufacturers such as Nissan, Subaru, Mazda, and Hyundai represent close to one-quarter of case vehicles with a number of other manufacturers (e.g., BMW, VW, Land Rover) comprising 9% (n=16) of case vehicles. A comparison of the composition of the ANCIS database with that of the vehicle fleet under the age of 10 years will be examined in the future.

Figure 2 shows the distribution of case vehicles by market category, as defined in Newstead *et al* (2000). 'Large' vehicles formed 42.4% (n=72) of the sample followed by 'small' vehicles (n=66; 38.8%). 'Medium' size vehicles (n=9; 5.3%), 4WD (n=11; 6.5%) and 'luxury' vehicles (n=9; 5.3%) were similar in number in the sample.

[2] The ISS is calculated by summing the squares of the highest AIS code in each of the three most severely injured body regions.

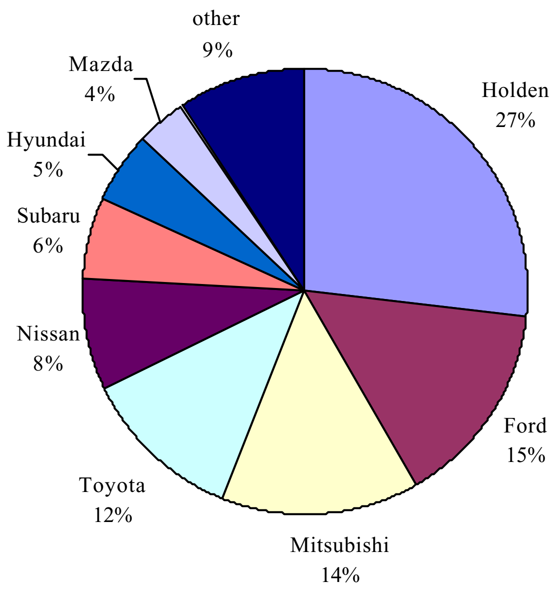

Figure 1. Case vehicles by manufacturer.

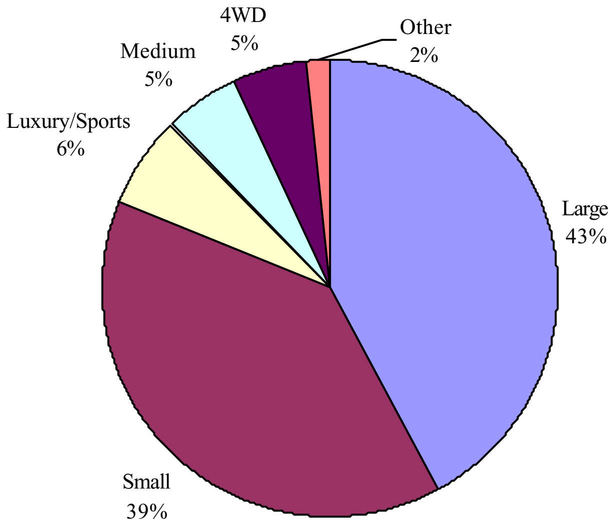

Figure 2. Case vehicles by market group.

Participant characteristics are shown in Table 1. Of the 170 participants, 57% (n=97) were male and 43% (n=73) Hence, male participants outnumbered females (1.3:1), and were more severely injured with a mean ISS of 16.4 compared with 12.7 for females, and this difference approached statistical significance, t(168)=1.84, p=0.06. While there was no difference in the mean age between males and females, there were statistically reliable differences in the height and weight of the two groups. The anthropometrics of participants is potentially important for the selection of the dummies for countermeasure evaluation.

Table 1. Participant characteristics by sex.

Participants (n=170)	**Males (57%; n=97)**	**Females (43%; n=73)**	**Significance**
Age (n=170)	Mean: 38.1 yrs (*SD=17.8)* Median: 33 years Range: 4 – 87 yrs	Mean: 38.8 yrs (*SD=21.1)* Median: 35 years Range: 1 – 85 yrs	t(168)=0.83, p=0.8
Height (n=163; 93 males)	Mean: 176.6 cm (*SD=10.2)* Median: 178 cm Range: 120 – 201 cm	Mean: 162 cm *(SD=10.6)* Median: 164.5 cm Range: 120 – 180 cm	t(161)=8.6, p 0.001
Weight (n=168; 95 males)	Mean: 82.1 kg *(SD=18.1)* Median: 83 kg Range: 24 – 140 kg	Mean: 62.4 kg *(SD=20.8)* Median: 60 kg Range: 12 – 150 kg	t(166)=6.5, p 0.001
ISS	Mean: 16.4 (*SD=13.9)* Range: 1 – 75	Mean: 12.7 *(SD=10.6)* Range: 1-50	t(168)=1.84, p=0.06

The ANCIS entry criteria and participant approach method ensures that the generally more severe cases are considered (with the exception of fatalities), as shown by a comparison between the distribution of impact types of ANCIS and the TAC[3] Claims File 2000 in Figure 3. Patients admitted to hospital with less severe injuries are often discharged within a day or two and may be missed by the ANCIS participant admission method. The under representation of frontal crashes is likely a consequence of this, as advances in frontal impact protection appear to be leading to less severe injuries.

[3] The Victorian Transport Accident Commission is a government-owned organisation that pays for the treatment and benefits for people involved in transport accidents. TAC data covers 1251 hospitalised sample vehicle occupants in cars manufactured 1991 onwards.

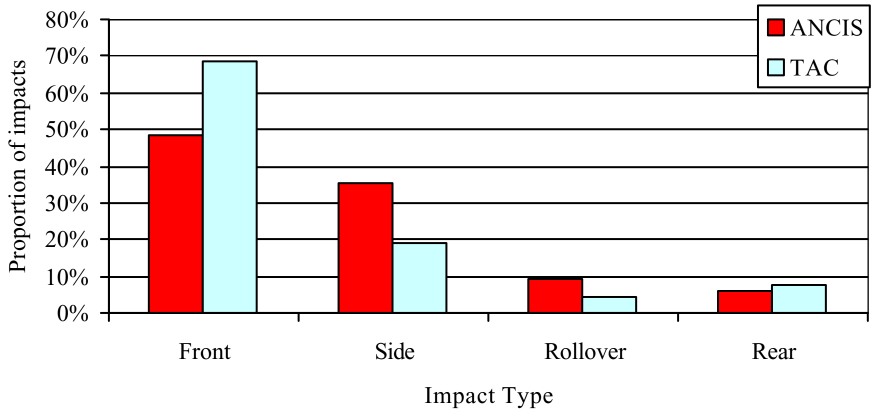

Figure 3. Impact classification by impact type.

The mean ISS for the whole sample was 14.8 (12.7) and ranged from 1 – 75. Occupants involved in side impact crashes sustained the most severe injury outcome, as measured by ISS, with a mean ISS of 16.7 (*SD=15.5; 1 – 75; n=60),* followed by occupants involved in rollover crashes (*Mean=15.3; SD=12.9; 1-42; n=16),* and frontal crashes (*Mean=14.4; SD=12.9; 1-41; n=82)*. Occupants involved in rear-end impacts sustained the lowest severity injuries as a group with a mean ISS of 8.6 (*SD=6.5; 1 – 19; n=10)*. Despite the apparent differences in the mean ISS of the four impact type groups, these differences were not statistically reliable, perhaps due to the small sample size, F(3,164)=1.3, p=0.2.

With respect to main collision partners, passenger cars and derivatives represented 33% of all collision partners, followed by trees (25%), poles (10%), trucks (6.6%) and 4WDs (6.1%). Roadside objects, roadside furniture, and other vehicles such as motorcycles represented the remaining collision partners.

The mean Delta-V for the sample where such a calculation is relevant and possible was 50.2 km/h (*SD=30.8 km/h; 93 cases)* while the mean EBS for the sample was 47.6 km/h (*SD=28.1 km/h; 138 cases).* Approximately half of all occupants were admitted following crashes in urban areas, 45% suffered a crash in rural areas, with the remaining 5% of persons having crashed in a mixed urban/rural environment. The mean delta-V of crashes having occurred in rural regions was 66.2 km/h (Mean EBS: 58.6 km/h), followed by regional areas (Mean dV=42.8; EBS=48.5), and crashes in urban areas (Mean dV=37.9; EBS=38.6) with the difference in delta-V and EBS being statistically reliable (dV: F(2,90)=11.2, p 0.001; EBS: F(2,135)=9.0, p 0.001), and post-hoc tests demonstrating that the difference rests between crashes in the rural and urban areas (p 0.001). In the cases where the delta-V was known, the mean ISS between rural (15.7; *SD=14.5*), urban (16.2; *SD=12.5*), and mixed (21.8; *SD=16.3*) did not differ statistically, F(2,90)=0.6, p=0.5. Similarly, in cases where the EBS was known, the mean ISS between rural (14.8; *SD=12.9*), urban (14.2; *SD=11.8*), and mixed (21.8; *SD=16.3*) did not differ statistically, F(2,135)=1.3,p=0.2.

The relationship between impact direction, impact severity and injury severity was examined. With respect to frontal impact crashes, the delta-V was 57.9 km/h for car-car (mean ISS of 11.6) and 63.6 km/h for car-pole (mean ISS of 18) crashes. While the mean difference in frontal car-car and car-pole crashes was not statistically different [t(47)=0.5,p=0.5], the mean ISS between the two groups was borderline statistically significant, t(47)=1.9,p=0.06].

In side impact car-car crashes, the mean delta-V was 35.0km/h with an associated mean ISS of 18.5, while car-pole side impact crashes were of similar delta-V (Mean=34.9km/h), although persons in this collision type had a higher mean ISS (Mean =23.1). There was no difference in the mean delta-V or mean ISS (p=0.5 and p=0.9 respectively) between the two groups.

Table 2 shows the distribution of MAIS2+ injuries by collision partner and body region for all occupants and for car-car and car-pole/tree impacts where the EBS was known. Overall, upwards of 80% of all occupants sustained an MAIS2+ injury, with nearly 50% of the sample sustaining an MAIS2+ injury of the chest, one-third sustaining an injury to the lower extremity, and approximately 25% sustaining an MAIS 2+ injury to the head and upper extremity.

Table 2. MAIS2+ injuries by body region for all cases, and cases where EBS is known.

Body Region MAIS2+ injuries	**Impact Type**			**Impact Type#** (EBS known)			
	All (n=170)	**Car-Car (n=56)**	**Car-Pole/Tree (n=61)**	**Car-Car (n=51)**	**Car-Pole/Tree (n=51)**	**Adjusted Relative Risk Estimate**	**Sig. p-value**
	%	%	%	%	%		
Head	22.9	14.3	32.8	13.7	29.4	2.5 (0.92-6.9)	0.07
Face	11.2	7.1	8.2	7.8	9.8	1.1 (0.27-4.7)	0.8
Neck	4.1	5.7	7.1	5.9	Nil	-	-
Chest	45.3	48.2	44.3	47.1	45.1	0.91 (0.41-2.0)	0.8
Abdomen	18.8	19.6	24.6	21.6	25.5	1.3 (0.51-3.2)	0.6
Spine	16.5	12.5	18	11.8	19.6	1.5 (0.48-4.7)	0.4
Upper Ex.	25.9	19.6	29.5	19.6	31.4	1.7 (0.68-4.3)	0.2
Lower Ex.	36.5	37.5	47.5	39.2	52.9	1.6 (0.74-3.6)	0.2
Burns	Nil	Nil	Nil	Nil	Nil	-	-
All regions	84.1	83	88.5	80.4	92.2	2.7 (0.8-9.6)	0.1

Cases only where EBS known to correct for EBS in logistic regression model.

In examining whether there are any differences in the proportion of occupants sustaining MAIS 2+ injuries between persons involved in car-car and car-pole crashes, it is necessary to control for crash severity. Columns 5 – 8 in Table 2 examines only cases where the EBS is known. After controlling for EBS, it is evident that the risk of sustaining an injury to the head in car-pole crashes is 2.5 times greater than the risk in car-car crashes. While none of the other comparisons within body regions are statistically significant, there is a trend for a greater risk of MAIS 2+ injuries in car-pole crashes relative to car-car crashes, with the exception of MAIS2+ chest injuries.

The characteristics of single vehicle and multiple vehicle crashes

Significant improvements in vehicle safety have been realised since the introduction of the first Australian Design Rule over 30 years ago, but while there are undoubtedly still advances to be made, it could be argued that the vehicle alone should not be expected to protect its occupants in all crash situations.

Since the enhancement of the ANCIS study to include scene information, it has become possible to examine factors relating to the road environment. The following results have been separated into single and multiple vehicle crashes, as they are quite different in terms of the role of the road environment, as well as injury outcomes and the potential countermeasures that might be employed to mitigate injury severity. A total of 164 cases were considered, of which 74 were single vehicle crashes (43.5%) and 90 were multiple vehicle crashes (52.9%). These are considered in turn.

Single Vehicle Crashes

Table 3 shows the distribution of single vehicle crash types by Definition for Classifying Accidents (DCA) code, an accident classification system used by the police to define the primary collision event.

Table 3. Distribution of DCA types, single vehicle crashes.

DCA Type (Primary Impact)	**Distribution**	
	Frequency	**Percentage**
Off path on straight into object (DCA=171 / 173)	35	47.3
Off path on curve into object (DCA=181 / 183)	23	31.1
Off path on straight, to left (DCA=170)	5	6.8
Off path on curve (DCA=180 / 182)	2	2.8
Other	9	12
TOTAL	**74**	**100**

Interestingly, the total percentage of occupants in vehicles leaving the carriageway on straight sections (47%) outnumbered those leaving the road on curved sections (31%). Of the occupants involved in single vehicle crashes, 57% occurred in rural areas, and in none of the crashes was there a runoff barrier of any type. Figures 4(a) and 4(b) show the distribution of objects struck in single vehicle crashes.

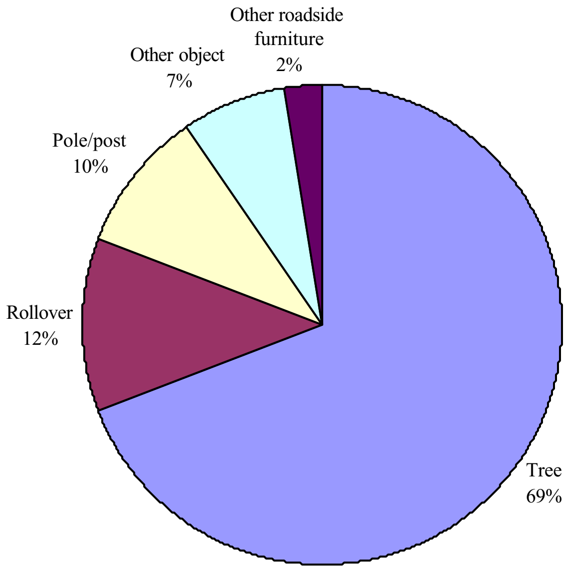

Figure 4(a). Object struck, single vehicle crashes in rural areas.

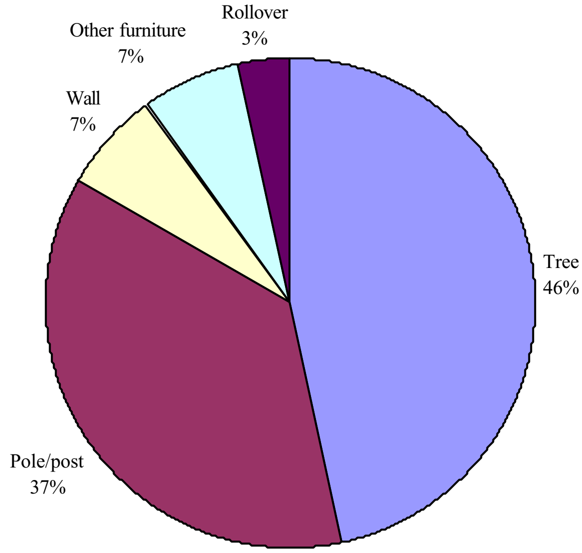

Figure 4(b). Object struck, single vehicle crashes in urban areas.

The majority of single vehicle collisions in both rural (79%) and urban (83%) crashes occurred with signposts, poles and trees. The speed zone in 71% of rural crashes was 100 km/h while approximately 34% of SVA urban crashes occurred in 60 km/h zones with 28% in 80 km/h zones.

A total of 48% of rural single vehicle crashes occurred on sealed roads with sealed shoulders and a further 31% on sealed roads with unsealed shoulders. All urban crashes occurred on sealed roads. More than half of the single vehicle crashes in all localities occurred on flat roads with around half in daylight.

Multiple Vehicle Crashes

Table 4 shows the distribution of multiple vehicle crash types by DCA code.

Table 4. Distribution of DCA types, multiple vehicle crashes.

DCA Type (Primary Impact)	Distribution	
	Frequency	Percentage
Head On	23	25.6
Cross-Traffic, intersection	21	23.3
Same direction, rear end	11	12.2
Right thru, intersection	5	5.6
Emerging from driveway	4	4.4
Lane change, vehicles travelling same direction	3	3.4
Right rear, vehicles travelling same direction	3	3.4
Parked	3	3.4
Other	17	18.7
TOTAL	**90**	**100**

It is evident from Table 4 that one-quarter of multiple vehicle crashes were head-on crashes, followed by across traffic intersection crashes, with rear-end crashes figuring prominently.

Figures 5(a) and 5(b) show the distribution of objects struck in multiple vehicle crashes. Two thirds of multiple vehicle crashes occurred in urban areas. Car-car impacts represent the majority of collision partners, with 4WD and trucks each representing approximately 10% of collision partners.

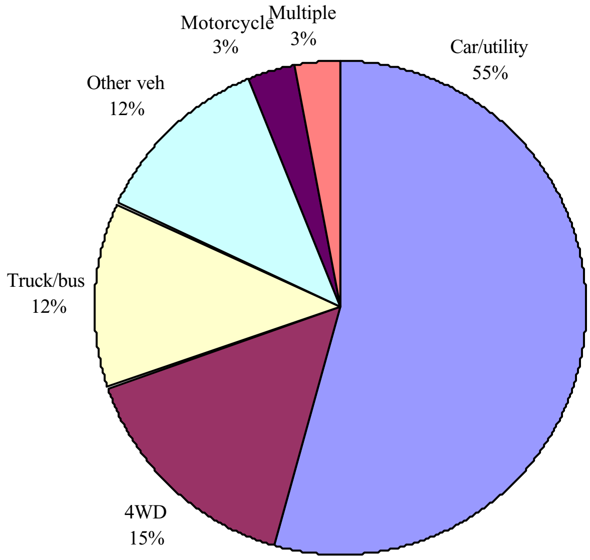

Figure 5(a). Object struck, multiple vehicle crashes in rural areas.

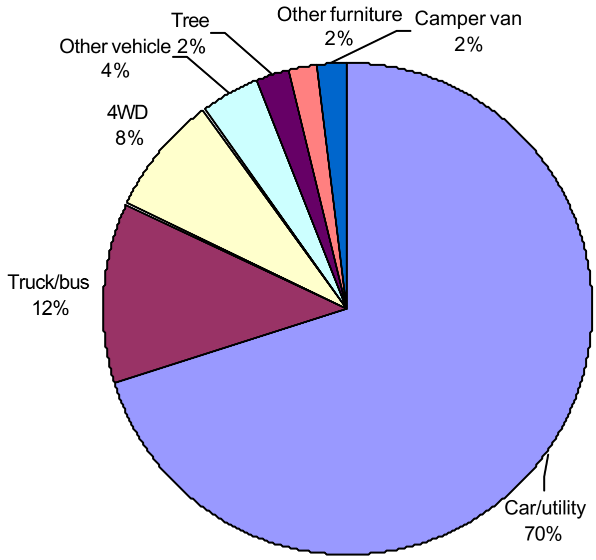

Figure 5(a). Object struck, multiple vehicle crashes in urban areas.[4]

With respect to speed zone, 81% of rural multiple vehicle crashes occurred in 100 km/h speed zones, 6.1% in 110 km/h zones and 12% in 80 km/h zones. Approximately 60% of urban crashes were in 60 km/h zones, 19% in 80 km/h zones, 12.5% in 70 km/h zones and 6.3% in 100 km/h zones.

Median treatments in rural multiple vehicle crashes consisted of trees/shrubbery in 10% of cases. A divided median was present in 50% of urban crashes, comprising 34% trees/shrubbery, 14% concrete and 1.2% W-beam. Note that the median played a lesser role in adjacent direction crashes, as it was obviously discontinuous at intersection locations. None of the locations at which multiple vehicle crashes occurred had a runoff barrier of any type.

In 97% of the rural road cases and 98% of the urban road cases, multiple vehicle crashes occurred on roads that were either completely sealed or sealed with a gravel shoulder. Two–thirds of urban and rural crashes occurred on level roads, and two-thirds of urban and rural crashes occurring in daytime.

Discussion

As with the previous update (Shields *et al*, 2001), the specific entry criteria and depth of investigation results in a relatively slow and labour intensive case collection process, particularly with the recent instigation of crash scene data collection that adds a further dimension to be explored. For this reason, whilst full-scale data collection has been in progress in NSW for around three months, only four cases have been included in the analyses presented here.

The ANCIS study method was not designed to capture a representative sample of crashes, but rather to analyse the occupant protection 'failures' where people are hospitalised through injury. Other sampling biases include the restriction to vehicles younger than 10 years, which may exclude certain socio-economic groups, and participants must give their consent to participate.

The predominance of tree, pole or post impacts in single vehicle crashes (81%) shows that there is significant work to be done, both in vehicle design to mitigate the injuries inflicted by such impacts, and also by road designers to reduce the number of such objects that are presented to motorists. The observation that two-thirds of single vehicle crashes occurred on straight roads indicates that the human factors behind this type of crash warrant further investigation, along with better information and feedback for the driver in the form of rumble lines, wider paved shoulders and better pavement marking.

More than half of multiple vehicle crashes are either intersection crashes (adjacent directions) or head-on crashes (opposite directions). Improved intersection control and separated carriageways may help to reduce this type of crash.

Future Developments

The variable set and forms used for ANCIS are currently in the process of being upgraded, with the following goals:

- To improve harmonisation with other in-depth investigation activities worldwide;

[4] Terminology: 4WD = SUV; a utility is generally a passenger car-based vehicle forward of the B-pillar, with a load tray behind.

- To increase the number of variables collected from the crash scene so that more detailed information on road infrastructure and environmental effects may be found.
- To improve the accuracy of crash severity measures. The software package CRASH3 has a number of limitations and possible replacements are under investigation at present.
- To develop means of determining the various human, vehicle and environmental factors contributing to crashes.

Negotiations are underway with the other Australian states and New Zealand with regard to broadening the data collection area as well as with the Coroner's Office for notification of fatalities, which are presently under-represented due to the hospital admission criterion. It is hoped that funding will be secured beyond the original contract period, which ends next year, in order that the increasingly detailed and valuable analyses made possible by larger data sets become possible.

Conclusion

A primary goal of the ANCIS study was to gain an improved understanding of the nature of injuries sustained in motor vehicle crashes. More recently, the study has been extended to determine the influence of a number of road environment and infrastructure factors. This is due to the recognition that motor vehicle crashes are the outcomes of a system in which not only the vehicle and its occupants interact, but also that the road environment plays a crucial role in the type and severity of crashes and thus injury outcomes. Despite the relatively small number of cases available for analysis to date, the incidence of single vehicle crashes into fixed roadside objects such as trees, poles and posts, intersection and head-on crashes, highlights the need for experts in human factors, vehicle and road design to work together to reduce the number of severe injuries suffered by vehicle occupants.

The latest enhancements to the ANCIS study permit the use of a systems approach to countermeasure development. For example, it has been encouraging to note that the disparate sponsor groups involved are acknowledging that vehicle designers and road designers must begin to cooperate, as neither is realistically able to prevent injuries to vehicle occupants in all circumstances.

Acknowledgements

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