Side Impact Crashes and Countermeasures

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Abstract – Side impact collisions are a major road safety problem in most western countries, accounting for up to 35% of all severe road trauma and the problem is not currently addressed effectively. While crash severities tend to be relatively low, the injuries sustained to occupants seated in the struck (near side) and non-struck or far side, tend to be severe and life threatening. The most common side impacts occur at intersections (car-car crashes) and pole or tree collisions (single-vehicle). Examples of in-depth examination of side impacts show severe damage to the car and the occupants from these crashes. The paper offers a range of countermeasures to reduce these impacts or mitigate the severity of occupant injuries.
Keywords: Side impact, intersection, pole, occupant injuries.

1 Introduction

Side impact collisions are a particularly severe and harmful type of crash for vehicle occupants. Depending on the severity of the crash, side impacts can be involved in up to 35% of road trauma and particularly noteworthy in fatal crashes [1,2]. Nearside impacts are commonly associated with side impact trauma, yet far side occupants can also be seriously injured in these crashes [1,3]. While some inroads have been made in improved frontal crash protection for occupants, the same cannot be said about side impacts and suitable countermeasures top address this trauma.

In trying to address how best to prevent or alleviate injury from these crashes, it is important to start off with a detailed understanding of the types of impacts, the patterns of injury and injury mechanisms, and the factors associated with their occurrence.

The objective of this paper was to undertake an analysis of recent side impact crashes in Australia and the USA to examine the patterns of crashes and injuries and the Harm associated with these crash types and what can be done to alleviate this trauma. Most police and insurance databases around the world lack sufficient data to conduct such an analysis. Hence, this study will confine itself to an analysis of retrospective in-depth crash data published by the National Automotive Sampling System - NASS/CDS in the USA and the Monash In-Depth Data System - MIDS – database from Australia.

2 Data Analysis

Analyses were undertaken of crash patterns in Australia and the USA to show the changing shift of crash types and recent increases in side impact collisions. Analyses of retrospective in-depth crash databases of NASS/CDS and MIDS was carried out to show side impact crash configurations and injury patterns in both countries. These databases comprise in-depth crash data for tow-away crashes and weighted to be representative of all crashes in their respective countries. A Harm analysis was also carried out to indicate the extent of trauma associated with side impacts and priorities for intervention.

2.1 Trends in Side Impacts

The findings in Fig 1 show that fatal side impact crashes have increased in their number and proportion over frontal crashes in recent years in Australia. [4].

The proportion of front crashes has become less while the equivalent side impact proportion has become larger. This probably reflects the greater success in addressing head-on crashes through frontal crash regulation followed by the introduction of seat belts and airbags to better restrain occupants from injury in these crashes. While side impact regulations have been introduced in these countries more recently, unfortunately, similar successes are not apparent in these crash types. In fact, the numbers of these collisions are at best stable or even growing in recent times [4].

Side impacts can occur to the occupant on the struck side (near side) or on the opposite side of the vehicle (far side). Past initiatives have focused almost exclusively on protecting the near side occupant as they generally experience the full force of the impact. However, 30 to 40 percent of the Harm experienced in a side impact crash occurs to the far side occupant and research is now focussing on how best to protect the far side occupant [5].

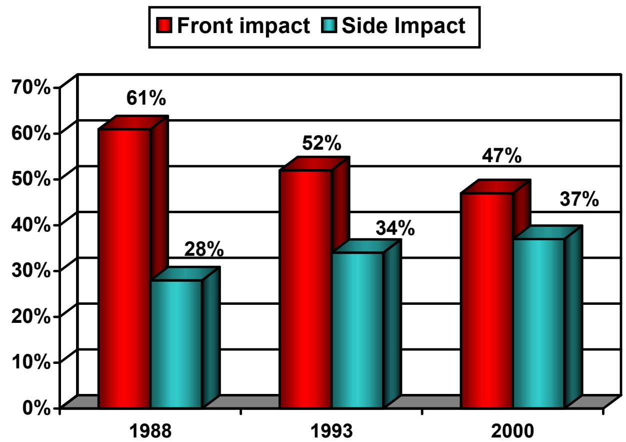

Fig. 1 Proportion of fatal front and side impact crashes in Australia, 1988 to 2000

2.2 Crash Severity

Figures 2 and 3 shows the crash severity distribution for side impacts based on in-depth crash data observed in Australia and the USA.

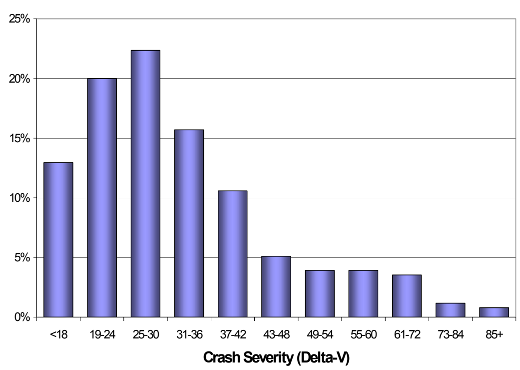

Fig. 2 Total crash severity for casualty side impact crashes in Australia

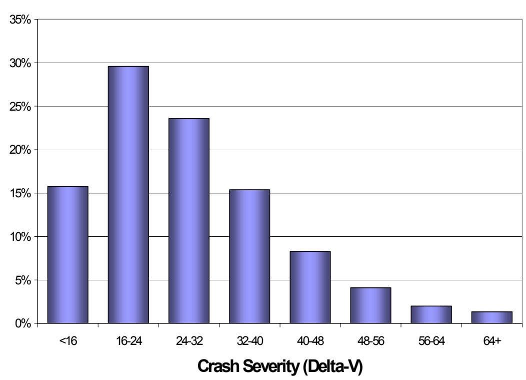

Fig. 3 Total crash severity for casualty side impact crashes in the USA

These figures show that the median crash severity for side impacts in both countries is between 24 and 32 k.m/h and that on average 90 percent of these crashes occur below 48km/h delta-V (88 percent in Australia and 92 percent in the USA).

2.3 Side Impact Injuries

Figures 4 and 5 show the proportion of body region injuries from side impacts in the USA and Australia, as well as the proportions by seating position.

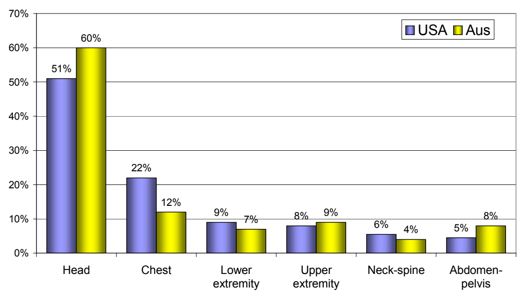

Fig. 4 Body region injured for severe (AIS3+) injuries by country

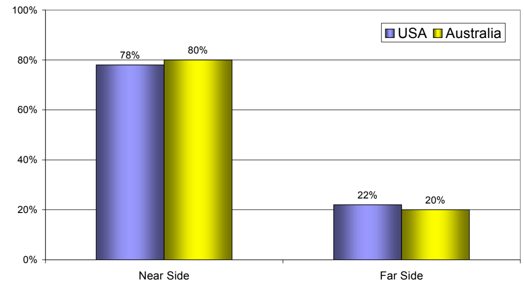

Fig. 5 Severe (AIS3+) injuries by near and far side crashes in USA and Australia

It can be seen that they predominantly involve the head, chest and abdomen and differ depending on seating position of the occupant. Moreover, there were very few differences in serious injuries sustained by vehicle occupants in near and far side crashes in either the USA or Australia.

2.4 Sources of Injury

Figure 6 shows the source of injury in side impacts. Injury sources in side impacts include the struck door, the impacting vehicle or object and other occupants when there are multiple front seat passengers.

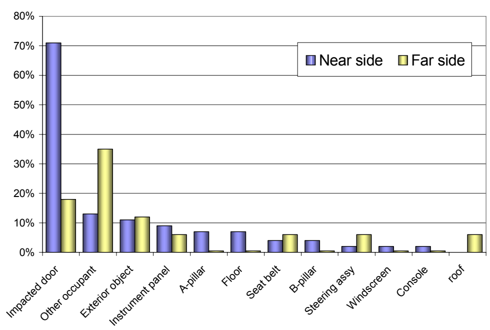

Fig. 6 Severe (AIS3+) injury contacts by near- and far-side crashes in Australia

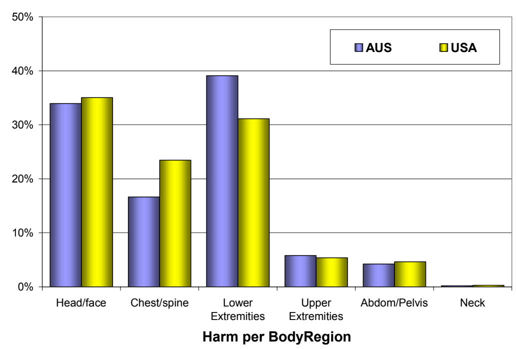

Fig. 7 Percent Total Harm to occupants in side impacts by country

2.5 Harm in Side Impacts

A Harm analysis was conducted for front seat occupants only in both countries, shown in Figure 7, with remarkably similar results. The major source of Harm from side impacts in both countries was to the head (over 30 percent) and the lower limbs (39-31%) followed by the chest and spine (17-23 percent), upper limbs (approx 6 percent) and abdomen and pelvis (5 percent). Although not shown here, the priorities for side impact protection based on the amount of Harm sustained included mainly front seat occupants struck by both another vehicle and/or a fixed object such as a pole [1].

3 CASE STUDIES

To further illustrate the findings above, two case studies are included below showing typical side impact crashes. These case studies involve an intersection crash between 2-vehicles and a single-vehicle side impact collision with a pole and were collected as part of the ANCIS study at MUARC in Australia.

3.1 Intersection Crash

This crash occurred around 22.30 at night, mid-week in Melbourne with dry roads and good weather. The case vehicle, a 2000 large family sedan, was proceeding through the intersection on a GREEN light when struck by a smaller sports sedan, which appeared to run a red light in the opposing direction. Photographs of the case and striking vehicle are shown in Photos 1 and 2.

Photo 1 Intersection crash case vehicle

Photo 2 Intersection crash striking vehicle

The crash occurred at an intersection between two divided roads (see Photo 3) and the case vehicle went on to collide head-on with a light pole as a secondary impact. The case vehicle contained a male driver aged 56yrs and a 51yr old front-seat passenger. Both these occupants were taken to hospital. The driver sustained the worse injuries in the crash as shown in Table 1 below. The passenger's injuries were bruises to the pelvis from perpendicular load transfer during the impact.

Photo 3 Intersection where crash occurred

Major Injuries	Abbreviated Injury Severity
Multiple rib farctures	3
Haemopneumothorax	4
Door contusions	1
Multiple abrasions	1

Table 1 Driver's major injuries

The causes on these injuries essentially involved the intruding door and the B-Pillar during the collision. The vehicle was fitted with a head-chest side airbag, which interacted with the driver and assisted in helping prevent a serious head injury. Neither of the two occupants suffered head injuries from the collision due to favourable crash kinematics. The driver of the impacting vehicle also suffered severe injuries, probably from contact with her steering wheel. The two occupants in the case vehicle were wearing their seat belts at the time of the collision but this could not be verified for the driver of the striking car. The case vehicle was also fitted with frontal airbags, which deployed successfully during the secondary crash.

3.2 Pole Collision

This was a run-off-road crash on a rural road in eastern Victoria on a Friday afternoon in May. The case vehicle, a small hatch-back sedan, was travelling downhill at dusk around a gentle right-hand curve when it lost control, rotating 90° before striking a tree sideways at the driver's door. The sole occupant, a 31-year-old female, was airlifted to a Melbourne trauma hospital, where she remained for eight days. She maintained that the road was wet and she lost control on its slippery surface (witnesses also claimed it was slippery from diesel fuel from an ageing truck that had just passed by).

Photo 4 The case vehicle

Photo 5 Site where crash occurred

The driver suffered multiple pelvic fractures (AIS 3) from impact with the front door, a highly comminuted fracture to the left distal radius (AIS 3) and an open dislocation of the left distal radioulnar (AIS 2) from the steering wheel, a small laceration to her spleen (AIS 2) from the seat belt, penetrating wounds to her right thigh (AIS 1) and her left medial calf (AIS 1) from the facia, and various other lacerations and contusions.

While there was some barrier protection from the trees in certain sections of the road, there was none in the particular region where she left the road and hit the trees (see Photo 5). The speed limit on that road was 100km/h. although the driver claimed to have only been travelling around 70km/h (delta-V was calculated to be 31km/h, suggesting her speed estimate was probably correct.

3.3 Summary Comments

These two cases were typical of the cases inspected in the MUARC in-depth studies. They show the severity of the crashes, the injuries sustained by the occupants and some of the factors associated with side impact collisions. As noted earlier, they are particularly severe impacts and especially harmful for the vehicle occupants involved. The use of in-depth data is particularly important for understanding the types of side impact collisions and what can be done to alleviate their frequency and severity. It's timely then to consider the range of interventions available to address this trauma.

4 Countermeasures

Countermeasures for side impacts fall into three broad categories, namely occupant, vehicle and road engineering solutions. Each of these will be discussed separately.

4.1 Driver Solutions

The most effective solution to any road safety problem is prevention; make sure that the event does not happen in the first place. Drivers make errors of judgement on the road and preventing these through better decision-making is essential. Driver solutions for fewer side impacts include the following:

- *Exposure reduction* – minimise the number of opportunities through avoiding dangerous situations and manoeuvres wherever possible.
- *Fitness to drive* – Drivers must be fit behind the wheel and capable of safe driving (eg; not drunk, tired, drugged or behaving recklessly). Being distracted from the driving task by inattention and poor vigilance is to be discouraged. Greater use of mobile telephones and other on-board distractions need to be discouraged.

- *Training & Education* – experience in safe driving is always valuable for preventing crashes. Lack of experience at avoiding dangerous situations has been shown to be a major road safety problem in most countries. Maintaining a safe and tolerant attitude to other road users is also important.
- *Speeding* - There is a growing body of evidence that associates driving at excessive speeds can lead to an increased risk of crash and injury involvement. Obeying speed limits and driving appropriate for the road and weather conditions is critical for safe driving.

4.2 Vehicle Solutions

Driver error is a predominant cause of involvement in side impacts and most crashes. While minimising driver error is a major thrust in road safety campaigns, it must also be recognised that humans do make errors and there some crashes are inevitable. Hence, we must also consider other ways to protect vehicle occupants involved in a crash by preventing or mitigating their injuries.

4.2.1 Side Impact Regulations

There are essentially two dynamic side impact standards in existence around the world: the US Federal Motor Vehicle Safety Standard – FMVSS 214 and the European ECE R95 Side impact regulation [6,7].

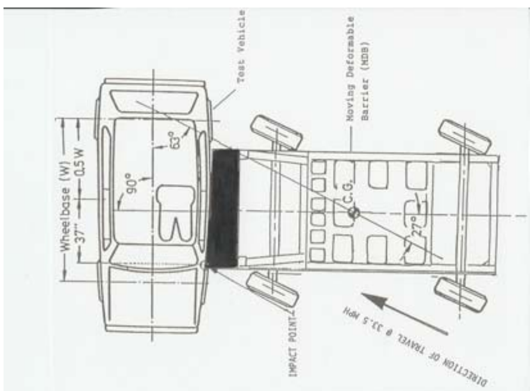

Fig. 8: US – FMVSS 214 Regulation

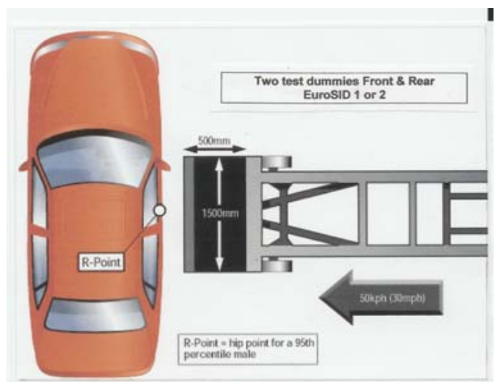

Fig. 9: European – ECE R69 Regulation

Both of these standards specify the type of crash manufacturers are expected to comply with as well as the minimum injury levels acceptable but they are fundamentally different requirements and seemingly impossible for a single vehicle to comply with both standards [8]. However, an analysis carried out by the Monash University Accident Research Centre showed that compliance with either of these two standards would provide similar Harm benefits [8]. In 1996 in response to calls for greater harmonisation of research and regulation activities around the world, the National Highway Traffic Safety Administration (NHTSA) in the USA formed seven International Harmonisation Research Activity groups to investigate a series of key vehicle safety issues. The development of a harmonised side impact standard was one of the key activities and participants from governments around the world set out to develop a uniform side impact regulation [9].

Almost 10 years later, a proposal for such a standard has been published [10], which involves a dynamic side impact barrier test, a pole test and component tests of the amount of door and roof padding. It is understood, though, that this proposal does not yet have the full support of all members of the IHRA committee. Indeed, the USA government has recently published a Notice of Proposed Rule Making detailing a separate side impact standard proposal [11]. The US auto industry though have cautioned against its introduction in that they claim that improved crash compatibility and consumer crashworthiness tests have already achieved significant side impact benefits [12].

Consumer tests in Europe and Australia also publish the results of side impact crash test performance using the European ECE R95 test procedure. In addition, the Insurance Institute for Highway Safety (IIHS) also conduct their own side impact test using the European test procedure and test dummy but with their own higher and more aggressive Mobile Deformable Barrier face to replicate SUV vehicle impacts [13].

Clearly, there is little agreement of what constitutes a harmonised side impact regulation for all vehicles. Perhaps it is ambitious to expect one, given differences in the various vehicle fleets around the world. However, it does make it difficult for manufacturers to build cars that are truly world-cars as they have to fashion compliance of their cars with the side impact requirements that exist in the country and market they are targeting.

4.2.2 Structural Improvement

Improved protection in a side impact is always going to be a challenge, given the minimal structure available to absorb the crash energy. Early focus was on providing structural members within the door to minimise the amount of intrusion from a pendulum test. However, research has since shown this approach did not really provide much in the way of protection and in some circumstances actually promoted spearing injuries to the occupants in these crashes.

Stiffer side structures seem to provide some injury prevention benefits, although this needs to be carefully managed. During the 1990s, Volvo announced the introduction of Side Impact Protection systems (SIPS) in their vehicles [14]. This involved reinforcing the lateral strength across the vehicle through the base of the seats to help transfer some of the load from the impacting vehicle or pole across the whole of the car. They claimed benefits of up to 26% for this initiative, although this still needs to be confirmed through independent research.

Photo 6 The SIPS system of rigid tubes in the seats and deformable steel box in the centre
(from Volvo website 2005)

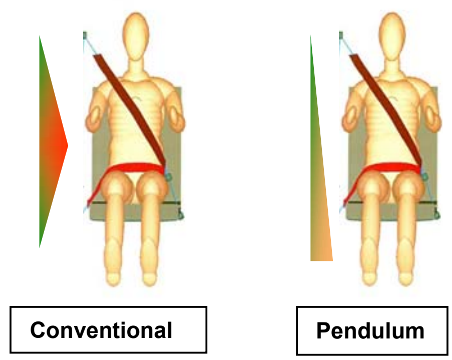

Photo 7 Pendulum design B-Pillar
(courtesy of Sparke [15])

Improved side impact performance through improved vehicle structure was found in vehicles that complied with the frontal offset barrier test. These design strategies include strengthening the side of the vehicle, which coincidentally improved side impact protection. Other manufacturers have addressed this by changing the design of the B-pillar to lower the point of maximum intrusion from around the chest level to the lower limb region. This pendulum effect is achieved by strengthening the B-pillar and it’s roof attachment and providing more scope for the pillar to intrude inwards at the lower sill attachment point [15].

Side airbags and door padding are additional design strategies aimed at mitigating injury to vehicle occupants in a side impact. There are a range of designs of side airbags from thorax airbags (door and seat mounted) to solely protect the chest, head airbags (tubes and cushions) to solely protect the head and combination airbags, which strive to provide both head and chest protection [16].

4.3 Road Engineering

The final area of intervention to reduce side impact Harm is in improved traffic engineering to either reduce the likelihood of the crash or mitigate impact energy. Roundabouts have been shown to be particularly effective at reducing crashes at intersections, with up to 36 percent savings in the number of crashes and 20 percent savings in injuries [17,18]. This is achieved by forcing motorists to stop or slow down in the approach to the roundabout as well as from changing the impact configuration from an injurious 90deg "tee-bone" collision to a less severe oblique crash. Other benefits have also been reported in reduced congestion through improved traffic flow and reduced vehicle emissions [19].

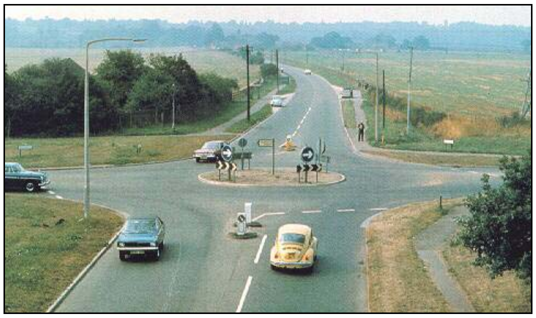

Photo 8 Roundabout intersection in US
(courtesy of NHTSA website)

Photo 9: Tree protecting barriers in Australia
(courtesy of VicRoads)

Pole and tree collisions are particular severe crashes generally but especially severe in side impacts, due to their rigidity and narrow surface. Above 20 or 30km/h, they can literally cut through a vehicle like a knife, inflicting severe damage to the vehicle and its occupants. One effective method of addressing these collisions in both urban and rural areas is by separating the vehicles from the poles through the use of roadside barriers and other protective devices. These devices have been particularly beneficial in reducing pole and tree collisions in Sweden and Australia [20,21].

5 Conclusions

Side impact collisions are a major road safety problem in most western countries, accounting for up to 35% of all severe road trauma and the problem is growing. While the crash severities tend to be relatively low, the injuries sustained to occupants seated in the struck and non-struck side (near side and far side) tend to be severe and life threatening. The most common side impacts occur at intersections (car-car crashes) and pole or tree collisions (single-vehicles). Examples of in-depth examination of side impacts show severe damage to the car and the occupants from these crashes. The use of in-depth data is particularly important for understanding the types of side impact collisions and what can be done to alleviate their frequency and severity.

Countermeasures to reduce these injuries comprise either crash avoidance or crashworthiness strategies. For drivers, these include exposure reduction, fitness to drive, training and education, and lower speeds. Vehicle countermeasures comprise effective side impact regulations, structural improvements and side airbags and padding. Road engineering is also likely to be effective for avoiding the crash where roundabouts at intersections and barrier protection from trees and poles seem to offer the greatest potential.

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