An Overview of Requirements for the Crash Protection of Older Drivers

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ABSTRACT

For some time now, it has been recognised that a major shift is occurring in the population age distributions of most motorised countries resulting in a growing number of older persons with an increasing need for mobility. It is expected that the mobility of older persons will become even more reliant on the motor vehicle as European countries in particular undergo transitions towards decentralisation and suburbanisation and because of the well-established longevity factor.
As a group, older drivers do not currently represent a major road safety problem in most Western societies when compared with other age groups such as the young. However, they are involved in significantly more serious injury and casualty crashes per head of population. Furthermore, as older drivers are likely to become a more significant problem in the years ahead, it is now necessary to examine some vehicle design factors that affect the safety of the older driver in a crash.

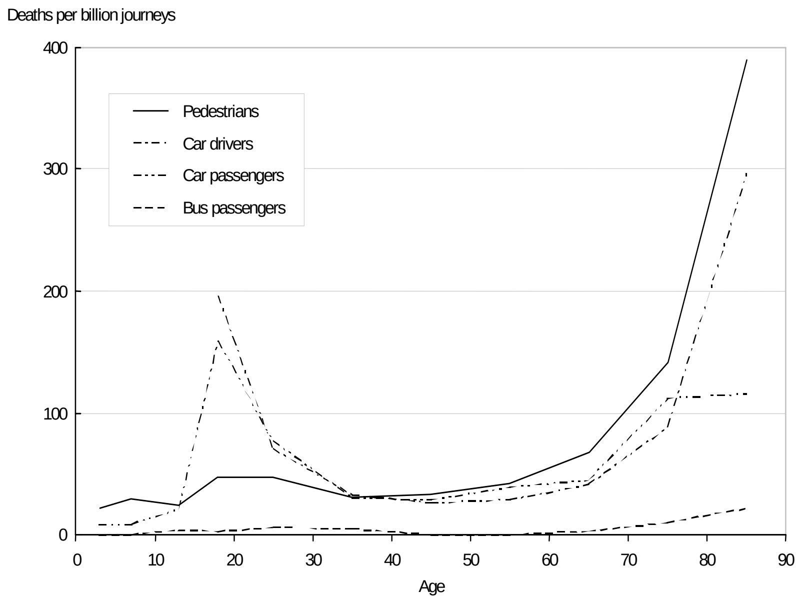
It is generally acknowledged that the energy required to cause an injury reduces as a person ages (Augenstein, 2001). It therefore follows intuitively that older drivers are more vulnerable to injury in a crash. Their skeletal structures are more easily damaged and the consequences of any assault are likely to be more serious compared with younger drivers (Dejeammes and Ramet, 1996; Evans, 1991; Mackay, 1989; Viano et al, 1989). As the population ages, there is a growing awareness of the need for vehicle safety to suit older occupants. In short, there is a need to improve the crashworthiness of vehicles to provide better protection for older drivers in the event of a crash.

The level of personal mobility and independence afforded by the motorcar is fundamentally important for older people. Many older people in western countries own their own car and make an overwhelming proportion of their trips in private vehicles (OECD, 2001). Over the next three decades, this pattern of travel is likely to increase at a rate consistent with growth in the number of older adults in the population. In many OECD countries, by the year 2030, one in every four persons will be aged 65 or over (OECD, 2001). The next generations of older drivers will bring a new set of challenges for road safety. The baby-boom generation will have grown up with the car, have higher licensing rates and will travel longer distances by car than persons of their parents' generation. As a consequence of the increased number of older drivers in the community and their greater reliance on cars for mobility, older driver safety is likely to become a bigger issue in the years ahead.

Some research indicates that older drivers do not represent a large road safety problem in terms of the number of crashes. However, older adults generally make shorter trips hence when crash statistics are adjusted for distance travelled, the safety concern for this group takes on greater significance. Recent Australian findings show that older drivers, particularly those aged over 75 years, are more likely to be involved in a serious injury crash per kilometre driven than other age groups (Diamantopoulou et al, 1996). In addition, fatality data for 1998 demonstrate that drivers in Australia over 75 years had a much higher risk of being killed per kilometre travelled compared with other adult age groups (Fildes et al., 2000). Indeed, in all OECD member countries, older drivers have higher fatality rates than other age groups (OECD, 2001). Figure 1 shows the fatality rate per journey by age group in Great Britain in 1998 (Mitchell, 2000, cited in OECD, 2001). The fatality rate for car drivers rises gradually from around age 45 to 65 years and thereafter, a dramatic increase is observed for drivers 50 to 80+ years. A similar pattern is observed for car passengers up until the age of 75 years, with a plateau beyond this age group. Vulnerability of older drivers is at least partially responsible for the over-representation of older occupants in fatal and serious injury crashes.

While the current crash figures for older drivers pose a high level of concern for road safety, expected changes in population demographics are likely to magnify the problem. Research in the US by Hu et al (2000), suggests that over the next three decades, fatal crashes could be as much as three times greater than at present without active intervention. Their model, which predicts a 286% increase in older driver fatalities, is predicated on four key factors: an increase in the proportion of older people in the population; an increase in the distance travelled by this group; an increase in the number of licensed older drivers; and an increase in their crash risk. Using Hu's model, Fildes, Fitzharris, Charlton and Pronk (2001) showed similar patterns of increase in fatality rates for the Australian context.

Figure 1. Fatality Rate per Journey, Great Britain 1998.



However, although there is much data concerning the declining functions associated with ageing and potential in-vehicle counter-measures, the differences in injury outcomes in vehicle crashes are a largely unknown factor. The ageing process is thought to reduce tolerance to crash forces (Mackay, 1989; Viano et al, 1989) because of reductions in bone strength and fracture tolerance. The influence of osteoporosis particularly on females is now well established (Berthel, 1980). Nevertheless, although manufacturers have an increased awareness of the changes that take place in the ageing process, the body of knowledge upon which effective crash protection design is based is still relatively small, particularly regarding the needs of the elderly driving population (Mackay, 1989). In one study, Foret-Bruno (1978, 1989, in Dejammes and Ramet, 1996) concluded that the most elderly population could withstand a chest load of 5,000N (equating to 50mm of force-deflection on the Hybrid-III dummy) whilst the younger population could withstand a chest load of 8,000N (equating to 80mm of force-deflection in the Hybrid-III dummy). The implications of this are that older occupants may be several times more likely to sustain a life-threatening chest injury (Padmanaban, 2001) and this can occur in a relatively moderate crash (Augenstein, 2001). The chest is clearly a vulnerable area and the major load bearing area for restraint systems as well as a major point of contact with the vehicle structure during a crash.

This study is the first of a series of studies examining the older vehicle occupant in details. Such studies are necessary in view of the growing recognition of the increase in the numbers of elderly drivers in most westernised societies. Moreover, as noted by Mackay and Hassan (2000), more detailed crash data are needed to optimise vehicle crash performance.

METHOD

UK in-depth crash injury data covering current model cars are analysed in this study. These data were collected between 1998 and 2001 as part of the on-going Co-operative Crash Injury Study. The CCIS data use a stratified sampling criterion for crashes to be investigated. Some 80% of 'serious' and 'fatal' and some 10-15% of 'slight' injury crashes according to the UK Government's classification are investigated. Consequently, the resulting sample is biased towards the more serious crashes.

In total, some 1,541 single impact vehicle crashes were studied. The un-weighted sample contains belted drivers including 889 drivers aged between 17-39 (younger drivers), 515 aged between 40 and 64 years (middle-aged drivers) and 137 aged 65 years and over (older drivers – range 65 to 84 years). Data from medical records were obtained from hospitals to which the drivers were admitted. All vehicles in the study were less than six years old at the time of the crash and were towed away from the crash scene. An in-depth examination of each vehicle was made in recovery-yards and garages within a few days of the accident. The UK Government system of injury classification was used to assess and compare the severity of driver injury in the datasets. This system classifies injured drivers approximately as follows;

Fatal	Death within 30 days of the crash
Serious	Injury serious enough to warrant hospitalisation or injuries such as fractures, severe lacerations etc.
Slight	Injury requiring minor treatment at an outpatient's ward or at the roadside.
No injury	No reported or observed injury.

In addition, individual injuries were coded and described according to the Abbreviated Injury Scale 1990 revision. Passengers were not considered in this study; a separate study of crashes involving older passengers is being prepared.

Chi square analyses were used to examine the relationship between age group (3 levels) and a number of variables of interest. In addition, separate one-way Analyses of Variance were used to investigate differences in crash

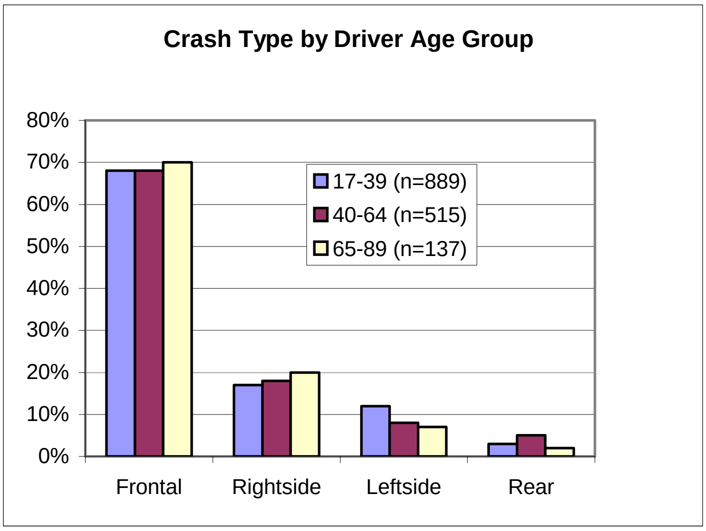
severity (EBS, km/h) across the three age groups (3 levels) for each crash type of interest. The null hypothesis being tested was that of equal distribution or value of the key variable across the 3 age groups. Results were seen to be statistically significant if the probability of obtaining the result due to chance was less than 0.05 based on a two-tailed test, in which case the null hypothesis was rejected.

RESULTS

1. Characteristics of Older Driver Crashes

The first analysis studies some characteristics of older driver crashes when compared to crashes involving somewhat younger drivers. Figure 2 shows crash types in the sample by driver age group.

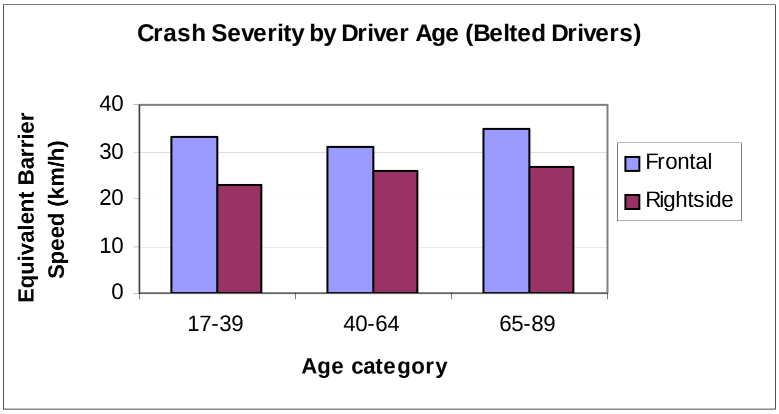
Figure 2



A chi-square test supports the observation that there is little relationship between crash type and age across the three age groups (χ^2 = 9.065, d.f. = 6, p=n.s.) although the older drivers are involved in slightly more frontal and struck-side (i.e. 'Right-side') crashes and slightly fewer non-struck side (i.e. 'Left-side) and rear impacts compared to the 'young' and 'middle-aged' group. The number of airbag deployments was examined for frontal crashes; 46% of the 17-39 age group, 47% of the 40-64 age group and 48% of the 65+ age group were involved in frontal crashes in which the airbag deployed. There were no cases of side airbag deployments in the sample.

Figure 3 shows the crash severity for the three age groups according to crash type. Only Frontal crashes and Right-side crashes have been studied in this analysis.

Figure 3



As can be seen from figure 3, there appears to be little difference in the mean crash severity for frontal impacts, as measured by the Equivalent Barrier Speed (EBS). In support, an ANOVA for each impact type produced non-significant results ($F_{.05}$ (2, 794) = 1.956, p = n.s for frontal impacts and $F_{.05}$ (2,119) = 0.687, p = n.s. for side impacts). The collision severity according to airbag deployment was also examined for frontal impacts and this analysis is shown in table 1.

As there were no cases of side impact airbag deployments in the sample, this analysis was not repeated for right-side crashes. It should also be noted that collision severity could not be obtained for all crashes.

Table 1; Crash Severity and Airbag Deployment by Driver Age – Frontal Impacts

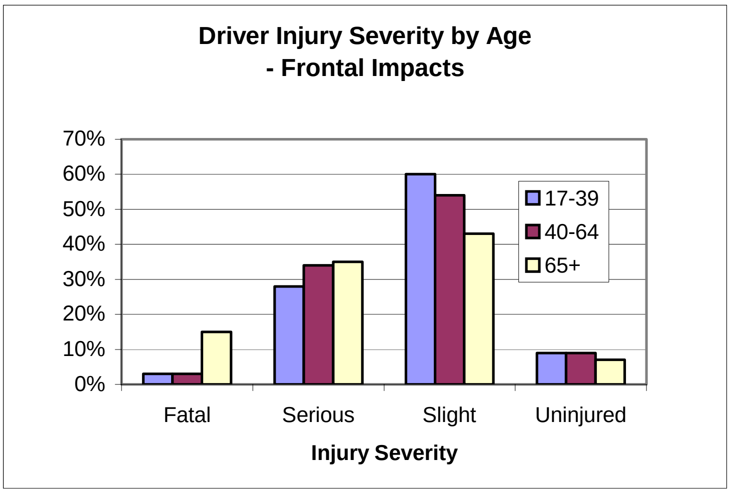
Age	17-39		40-64		65+	
Airbag Status*	no airbag (n=242)	airbag (n=219)	no airbag (n=134)	airbag (n=122)	no airbag (n=40)	airbag (n=39)
Mean EBS	32.0	33.1	32.0	30.3	36.1	33.5

*No airbag = no steering-wheel airbag fitted or no deployment
Airbag = steering wheel airbag fitted and deployed

2. Injury Severity and Driver Age

Figures 4 and 5 show injury outcomes (according to the UK Government's classification of crashes) by crash type for the three groups of drivers. A chi-square test allows the null hypothesis of equal distributions at the 95% significance level to be rejected, though not disproved (χ^2 = 34.8, d.f. = 6, p<0.001). Observationally older drivers appear to be over-represented in the 'Fatal' injury classification for frontal impacts. This is the case, even though as was shown above, the nature and severity of crashes in which they are involved do not differ statistically when compared with the other groups of drivers (i.e. 'younger' and 'middle-aged' groups).

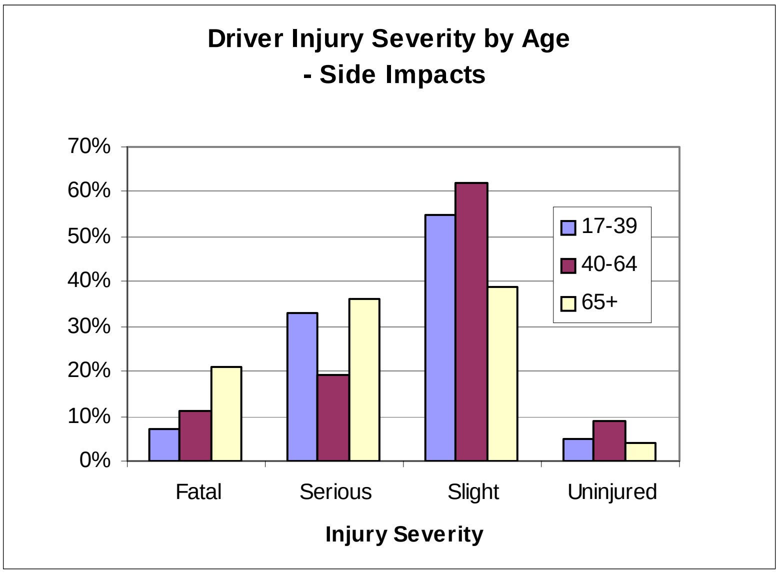
Figure 4



When side impacts are considered, a chi-square analysis supports the observation that the distributions of driver injury severity according to driver age vary (χ^2 = 14.05, d.f. = 6, $p<0.05$). Observationally (figure 5) the older drivers appear to be over-represented in the 'Fatal' injury category.

It can also be seen from figure 5 that in addition to the 'older' group, a relatively high proportion of the 'younger' age group of drivers sustained serious injuries when compared with the 'middle-aged' group. The reason for this is not immediately clear but possible explanations include differences in object struck, vehicle type, size of vehicle and other such factors that were not considered in detail for this particular study.

Figure 5



The influence of the driver airbag on injury outcomes in frontal impacts was also examined. This analysis is shown in table 2.

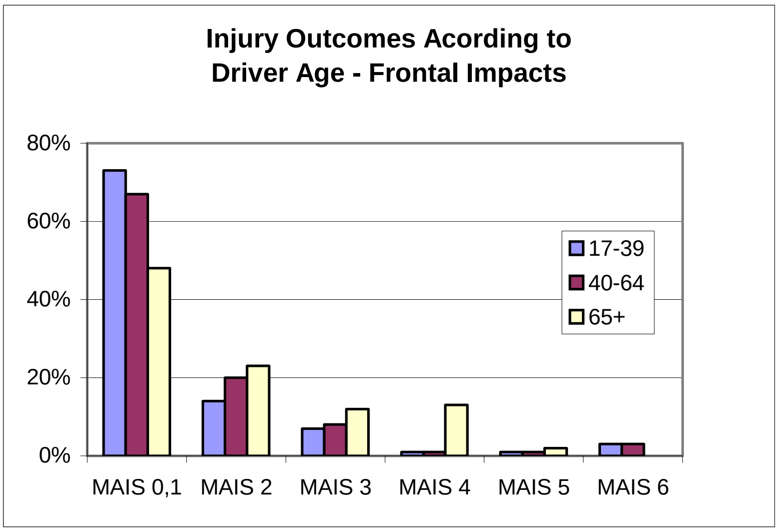
Table 2; Injury Outcome by Airbag Deployment

	17-39		40-64		65+	
	airbag	no airbag	airbag	no airbag	airbag	no airbag
Fatal	2.5%	4.0%	3.2%	3.0%	10.9%	18%
Serious	33.5%	23%	31.9%	36.7%	41.3%	30%
Slight	59.7%	59.5%	54.6%	52.4%	36.9%	48%
No Injury	4.3%	13.4%	10.3%	7.8%	10.9%	4%

As can be seen from the table, the airbag appears to have an influence on injury outcomes in some cases although the overall effect was not studied in its entirety since there are many confounding factors that need to be taken into account which were considered to be beyond the scope of this present study. Airbag effectiveness was not studied in side impact crashes since there were no instances of side airbag deployment in the sample.

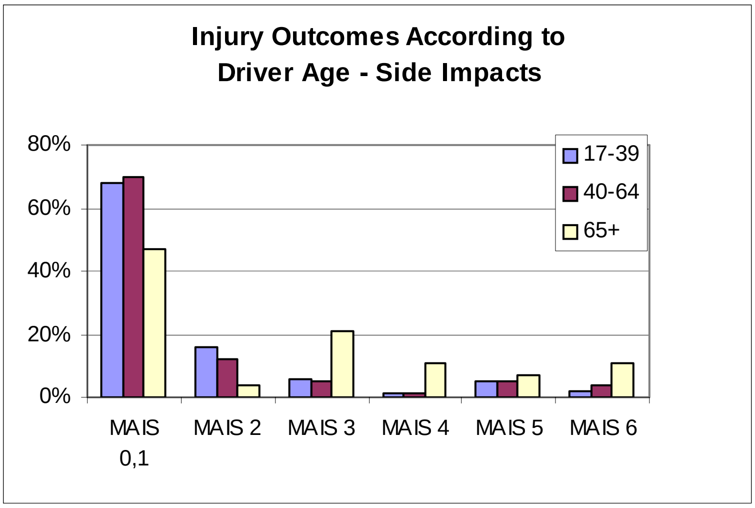
Figures 6 & 7 show actual injury outcomes (according to the Maximum Abbreviated Injury Scale score) by crash type according to driver age. In figure 6, drivers in frontal impacts are considered. Differences in the overall distribution of MAIS across the age groups were supported ($\chi^2 = 68.6$, df = 12, $p<0.0001$). Observationally, the results suggest that the older driver age group sustain more severe injuries, particularly at the MAIS 4 level although they also appear to sustain a greater proportion of injuries at the MAIS 2 and MAIS 3 level.

Figure 6



A similar finding was established in side impact crashes. Differences in the overall distribution were supported ($\chi^2 = 22.1$, df = 12, $p<0.001$). Observationally, the results suggest that the older driver age group sustain more severe injuries, particularly at the MAIS 3 and above level.

Figure 7

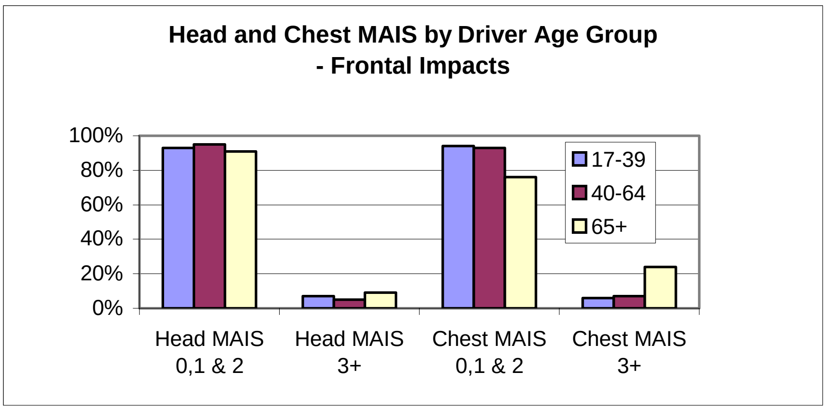


3. Injured Body Region and Driver Age

Given the differences in MAIS outcomes in both frontal and right-side impacts, the data were analysed further to look at injuries to specific body regions. All body regions were examined but the injury rates in most of the body regions were not statistically significant in each of the 3 groups.

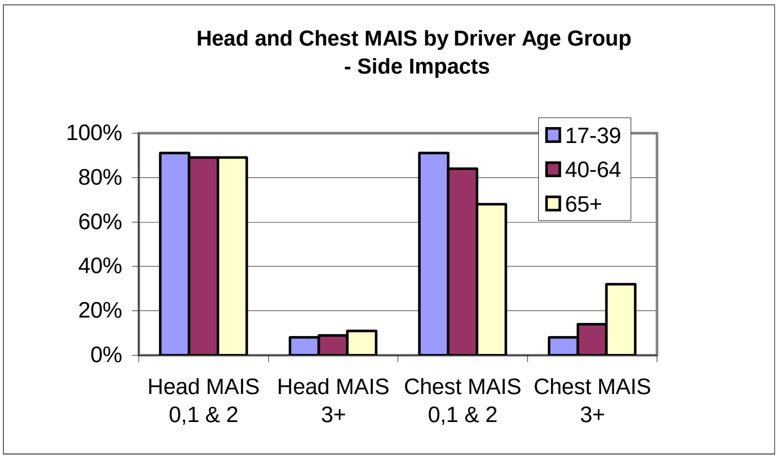
The head and chest regions were then further considered, as these were found to be the most frequent body regions injured. Figures 8 and 9 show the MAIS outcomes according to crash type and driver age group. A chi-square test allowed the null hypothesis to be accepted leading to the conclusion that the overall distributions for head injury outcomes across the three age groups in frontal crashes did not differ ($\chi^2 = 1.83$, d.f. = 2, p=n.s.). However when chest injuries were considered, differences in the overall distribution were supported by chi-square analysis ($\chi^2 = 45.55$, d.f. = 2, $p<0.0001$). Figure 8 shows that the older driver age group appear to sustain more injuries to the chest region at the MAIS 3+ level when compared to the other age groups

Figure 8



A similar result was found for drivers involved in right-side crashes. Here, there was no evidence to suggest that the driver head injury rates differed between the three groups of drivers and this is again contrary to intuitive expectations. However, when chest injuries were considered, differences in the overall distribution were supported by chi-square analysis ($\chi^2 = 15.49$, d.f. = 2, $p<0.001$). The older driver age group was observed to have a higher rate of injuries at the MAIS 3+ level (figure 9).

Figure 9



The influence of the airbag on head and chest injury outcomes was also examined. The results of this analysis are shown in table 3.

Table 3; Influence of Airbag on Head and Chest Injury Outcomes in Frontal Crashes

Head						
	17-39 years		40-64 years		65+ years	
	airbag (n=279)	no airbag (n=320)	airbag (n=166)	no airbag (n=185)	airbag (n=46)	no airbag (n=50)
MAIS 0,1 & 2	95%	92%	95%	95%	91%	90%
MAIS 3+	2.2%	4.7%	3%	4.3%	4.3%	8%
Chest						
	17-39 years		17-39 years		65+ years	
	airbag (n=279)	no airbag (n=320)	airbag (n=166)	no airbag (n=185)	airbag (n=46)	no airbag (n=50)
MAIS 0, 1 & 2	95%	93%	91%	95%	76%	76%
MAIS 3+	2.5%	4.7%	6%	4.3%	20%	22%

As can be seen from table 3, the airbag has an effect on reducing head injuries at the MAIS 3+ level. For drivers aged 17-39 years, the MAIS3+ head injury rate in the non-airbag group is over two times that in the airbag group. In the 65+ age group, the rate increases from 4.3% in the airbag group to 8% in the non-airbag group.

Morris et al
2002

The deployment of the steering wheel airbag appears to have a marginal effect on reducing chest injuries for all age groups. However, deployment of the airbag does not appear to explain the major difference in chest injury outcomes by driver age-group (as was shown in figure 8) since over 20% or more of drivers in the older age group sustain injury at the MAIS3+ level, regardless of presence or absence of the airbag.

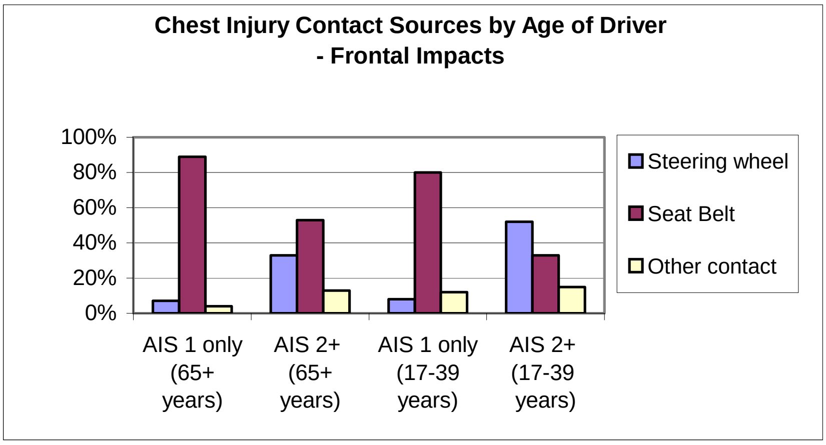
Airbag effectiveness on chest injury outcome in side impact crashes was not studied since there were no instances of side airbag deployment in the sample.

4. Injury Outcomes and Contact Sources

In both frontal and side impacts, the data in this study suggest that the chest is the most vulnerable body region for the older driver age group. In the sample studied, 20% or more of older drivers in frontal crashes (regardless of airbag deployment) and 32% of older drivers in right-side impact crashes sustained injuries at the MAIS 3+ level.

Given the risk of chest injury to older drivers in both frontal and side impacts, the nature and source of injuries were examined. Figure 10 shows the source of injuries to drivers by Abbreviated Injury Scale (AIS) score in the younger and older groups only.

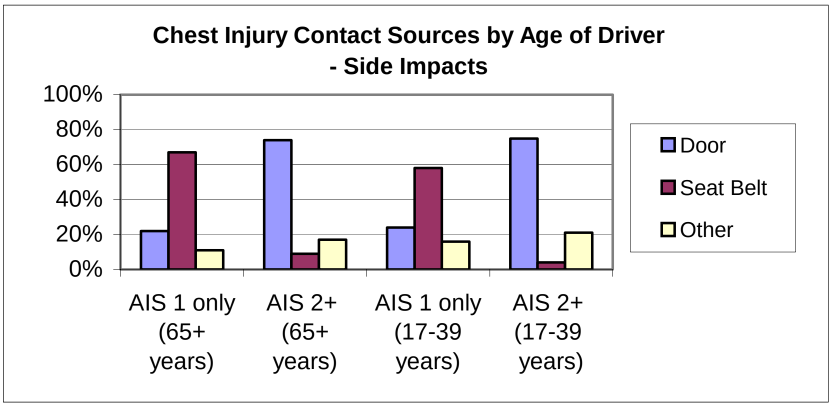
Figure 10



It was found that the seat belt and the steering wheel make up the majority of chest injury contact sources in frontal impacts. For both groups (younger and older), the main source of injury at the AIS 1 level was the seat belt. However, when injuries at the AIS 2+ level were considered, the seat belt proved to be the main source of contact for the older group. In contrast, the seat belt is a less important source of injury for the younger age group and the steering wheel assumes a greater significance for this group. The influence of the airbag in this analysis was considered but the data could not provide conclusive or informative findings due to paucity of data.

Figure 11 shows the injury contact source by AIS for drivers in right-side crashes.

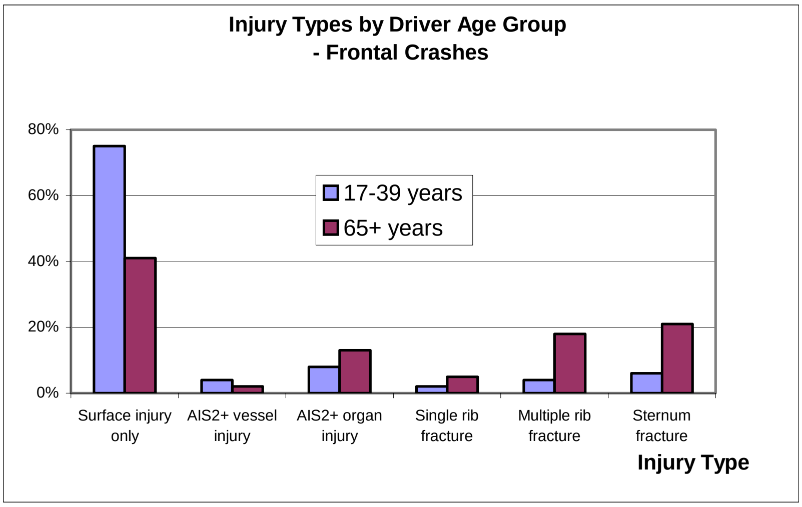
Figure 11



Here the injury contact sources are roughly equivalent with the door as the main source of contact at all injury levels for both age groups of drivers. This is an intuitive finding given the likely proximity of the driver to the door in the event of a crash.

Figures 12 and 13 show the injury types in frontal and side impact crashes by driver age group (younger or older).

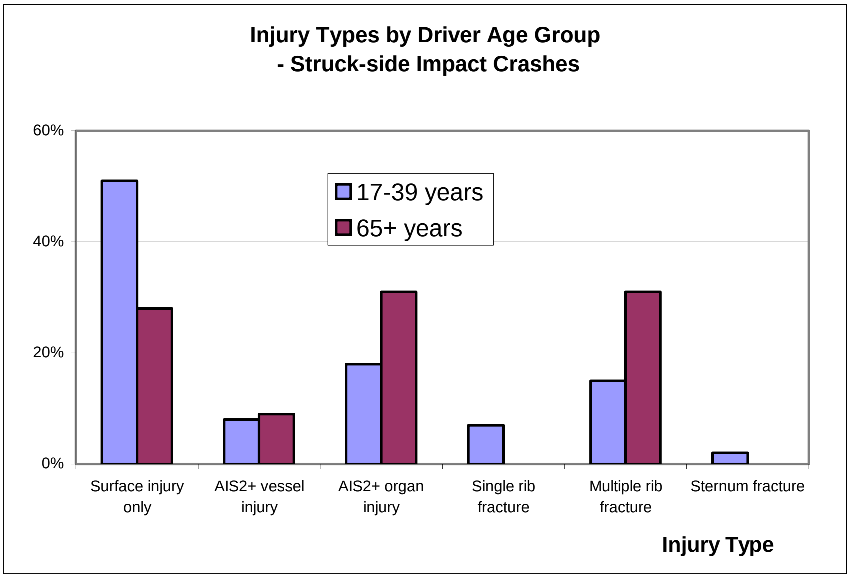
Figure 12



In figure 12, frontal impacts were considered and it was found that older drivers tended to sustain higher rates of AIS 2+ organ injuries (including particularly injuries to the lungs, heart and myocardium) both single and multiple rib fractures and sternum fractures.

In figure 13, the same effect is observed. However there is an even higher rate of AIS2+ organ injuries and multiple rib fractures in the older driver group compared to the younger driver group.

Figure 13



DISCUSSION

This study has found that given assumed similar crash conditions, older drivers appear to be more at risk of sustaining fatal and serious injuries in both frontal and right-side crashes. The older driver body region most prone to injury in either frontal or side impact crashes is the chest.

When injury rates to all other body regions are examined, there is no discernible difference in injury rate. Most noteworthy, there does not appear to be an association between age and head injury outcome. Whilst this finding may not conform to intuitive predictions that head injury risk increases with age, the available head injury biomechanics literature is also inconclusive about this issue. Paucity of data was not however thought to be the underlying explanation for this finding.

If predictions for the shift in population age distributions prove accurate, they indicate a need for intervention through vehicle design. Chest injury mitigation devices such as driver airbags, side airbags and load-limiting seat belt systems may be beneficial in this respect. However, there may also be a requirement to further refine seat belt systems so that biomechanical variation in tolerance to impact (due to age) is taken into account. Methods for providing for such variability could include load limiting or discretionary web-lock mechanisms, which could be calibrated for specific occupant characteristics such as age, sex, weight and height as Mackay (1994) suggests. It will also be important to monitor how effectively recent safety systems such as door and seat-mounted side airbags afford protection, particularly to the elderly vehicle occupant.

More data from real world crash analyses may help with the understanding of injury patterns and outcomes specific to crashes involving older adults and the relative protective influences of vehicle size and design features. Specifically, it would be most useful to know about the relative frequency and severity of injuries in drivers of different age groups involved in various configurations of crash types and vehicle design fittings. This type of analysis would better enable the identification of features associated with crash protection and would be useful for advising older drivers on specific aspects of vehicle safety. Passenger safety also needs to be considered and this will be the subject of a follow-up study.

Given the need to encourage older drivers to use and/or purchase vehicles with modern safety features, priority needs to be given to promoting awareness of vehicle safety issues amongst older people. The OECD report on Ageing and Transport (2001) notes that "older drivers need information on the implications of ceasing to drive, on the physical and cognitive changes experienced as part of the ageing process, and on the choice of safer vehicles".

Recent surveys commissioned by the Australian Automobile Association (AAA) reported a continuing belief amongst drivers that stronger and bigger cars offer more protection, whereas smaller ones were seen as less robust (AAA, 1997). In addition there was no consensus that new cars were generally any safer than older cars although new expensive cars were seen as having superior safety features. The study also reported age-related differences in awareness and attitudes about crashworthiness and specific safety features. For example, when asked about "*what aspects or features of a car help to make it safe in a crash*", only 51% of drivers aged over 55 years spontaneously responded that specific safety features (such as airbags and seatbelts) were important, compared to over 75% of drivers in the age groups 18-24 and 25-33 years. Other more recent research (Charlton et al, 2002) also shows that older people had a poor understanding of some safety features designed to improve occupant protection in a crash. Two key areas of misinformation amongst older people were found to be airbags and vehicle structure including the value of modern crumple zone design.

Therefore, there is also clearly much scope for promoting awareness of vehicle safety features across all age groups of drivers and particularly amongst the older population. This is likely to have a positive influence on safer vehicle purchasing patterns with better crash protection levels and demonstrable occupant safety benefits.

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