The impact of environmental, vehicle and driver characteristics on injury severity in older drivers hospitalized as a result of a traffic crash

Abstract

Introduction: Compared to younger age groups, older people are more likely to be seriously injured or to die as a result of a traffic crash. *Method:* The aim of the study is to examine the impact of environmental, vehicle, crash and driver characteristics on injury severity in older drivers involved in traffic crashes by using recently linked police crash records and hospitalization data from New South Wales, Australia. The severity of injury resulting from traffic crashes was measured using the International Classification of Diseases, 10th revision (ICD-10) Injury Severity Score (ICISS). *Results:* Multivariate analysis identified rurality, presence of complex intersections, road speed limit, driver error, speeding and seat belt use as independent predictors of injury severity in older people. The type of intersection configuration explained over half of the observed variation in injury severity, suggesting that environmental modifications such as intersection treatments, might contribute to a decrease in the severity of injury in older people involved in road crashes.

1. Introduction

While older people are less likely to be involved in road crashes than younger age groups, they are more likely to be seriously injured or to die as a result of a crash (Lyman, Ferguson, Braver, & Williams, 2002). It is generally recognized that the number of older drivers involved in traffic crashes is likely to increase significantly in the future with the ageing of the population in most industrialized countries. In the United States, it is estimated that, compared to 1999, there will be a 178% increase in the number of older drivers involved in police reported crashes and a 155% increase in the number involved in fatal crashes by 2030 (Lyman et al., 2002). Similar projections are expected in Australia where the population of older drivers is growing by 25% per decade (Australian Institute of Health and Welfare, 1997).

Recognition of these trends has resulted in a large body of research that has attempted to identify factors for traffic crash involvement among older drivers. Most of these studies have focused on the role of chronic medical conditions and/or functional impairments including vision, cognition and mobility in crash risk, rather than injury severity, per se (McGwin, Chapman, & Owsley, 2000; Lyman, McGwin, & Sims, 2001; Owsley et al., 2002; Anstey, Wood, Lord, & Walker, 2005).

There has also been a growing interest in the increased risk of severe injury in older road users involved in traffic crashes compared to younger road users. Various studies have examined the contribution of driver, crash, vehicle and road characteristics to injury severity in vehicle drivers involved in traffic crashes including older drivers (Kim, Nitz, & Richardson, 1995; Zhang et al, 2000; Zhang et al, 2000; Dissanayake & Lu, 2002; Austin & Faigin, 2003). However, these studies have often relied on the severity classifications found in police crash datasets, which generally categorize injuries into very broad categories of minimal, minor, major and fatal on the basis of police reports. While police crash data are the most valuable source of information on the circumstances of traffic crashes, the level of injury severity usually reported is often inaccurate (Rosman & Knuiman, 1994; Laumon & Martin, 2002). This is largely because injury severity is determined at the scene of the crash by non-medical data collectors from crash site observation alone.

While it is possible to use other datasets, such as hospital discharge data, for more reliable measures of injury severity in older drivers (Cunningham, Howard, Walsh, Coakley, & O'Neill, 2001), hospital discharge data, unlike police crash data, usually lack specific information on the circumstances leading to the vehicle crash. Record linkage of police crash and hospital datasets is one method that has the potential to overcome the limitations of both types of data, and allows the investigation of factors influencing injury severity in older drivers (Boufous & Finch, 2006).

This study examines the impact of environmental, vehicle, crash and driver characteristics on injury severity in older drivers involved in traffic crashes by using recently linked police and hospitalization data from New South Wales (NSW), Australia. The findings have the potential to contribute to improving knowledge of the outcomes of traffic crashes involving older drivers and to inform the development of sound road safety strategies to minimize injuries and injury severity in this particular road user group.

2. Methods

2.1 Case selection

Traffic crashes analyzed in this study were obtained from a database linking hospital separations from the Inpatient Statistics Collection (ISC) to police crash casualty records from the Traffic Accident Database System (TADS) in New South Wales, Australia. Hospitalizations as a result of a traffic crash were selected based on the fourth character of the International Classification of Diseases, 10th revision, Australian modification (ICD 10-AM) external cause of injury codes V01 to V89. A traffic accident is defined, according to ICD 10-AM, as any vehicle accident occurring on a public highway. Public highway refers to the entire width between property lines (or other boundary lines) of land open to the public as a matter of right of custom for purposes of moving persons or goods.

Probabilistic record linkage techniques were used to link the two datasets for the financial year 2000-2001. Matching variables included the surname, initials, phonetic coding of surname, date of birth, age, gender, postcode, date of the crash and date of hospital admission. For the purpose of this study, of the 944 hospitalized vehicle drivers aged 50+ years who were involved in traffic crashes with a primary diagnosis of injury, we have selected 825 (87.4%) who had a matching TADS record. The term “older drivers” is used to denote those aged 50+ years. This particular age group was selected to ensure comparable findings with the available literature in the area.

The ISC dataset was linked to TADS using probabilistic record linkage techniques that have been described in detail elsewhere (Newcombe, 1988). Probabilistic data linkage compares the values of common or matching variables and calculates the probability that pairs of records represent the same individual. Variables used to link datasets were assigned a linkage weight according to their “reliability” and “discriminative power.” For example, agreement on date of birth is more suggestive of a match than is agreement on sex. Therefore, matches on date of birth have a greater weight than sex.

In order to identify matches, the sum of comparison weights related to each matching variable and for each comparison pair is computed and the “cut-off” and the “threshold” weight values are set. If the sum of comparison weights for each record pair is below the 'cut-off' value, the record pair is rejected as “non-links.” If the total weight is above a much higher 'threshold,' the record pair is defined as a 'definite' or ‘true’ link. Records with values between the 'cut-off' and the 'threshold' are said to be 'possible links.” The final pool of ‘possible links’ was checked manually by one of the authors as well as an independent researcher based on a pre-specified criteria for exclusion of obvious mismatches.

2.3 Severity measure

The International Classification of Diseases (ICD-10) Injury Severity Score (ICISS) was used to measure the severity of injuries resulting from traffic crashes (Osler, Rutledge, Deis, & Bedrick, 1996). The ICISS, which is based on the ICD-10 classification, can be readily used with hospital discharge databases. It involves calculating a survival risk ratio (SRR) which is an estimate of the probability of survival for each individual injury diagnosis code, and is computed as the ratio of the number of patients with that injury code who have not died in hospital and the total number of patients diagnosed with that code. Thus, a given SRR represents the likelihood that a patient will survive a particular injury before discharge from hospital, with an SRR=1 representing complete recovery and SRR =0 indicating death. It is important to note that those who did not get hospitalized as a result of a traffic crash– especially those who died at the scene – were not included.

The ability of the ICISS to predict severity in terms of threat to life, was assessed in a study using both Australian and New Zealand hospital discharge data (Stephenson et al, 2004). The study showed that overall, the ICISS performed well, particularly when applied to Australian data, and confirmed the findings of previous work which indicated that when using large datasets, ICISS performs best in measuring injury severity compared to other severity measures such as the Modified Anatomic Profile, Anatomic Profile Score and the Injury Severity Score (Stephenson, Langley, & Civil, 2002).

2.4 Analysis

Univariate and multivariate linear regression analyses were carried out to determine the impact of selected independent variables, mainly found in TADS, on injury severity in older people who had been hospitalized because of a traffic crash.

2.4.1 Dependent variable (in ISC)

The dependent variable was the survival risk ratio (SRR) described above. As the SRR followed a left-skewed distribution, a logit transformation was used to transform the distribution before (Armitage, Berry, & Matthews, 2002). Values were transformed back to SRRs when presenting the results.

2.4.2 Independent variables (in TADS)

A number of independent variables describing the crash, road, environment and driver characteristics were selected based on previous research and on the availability and quality of data items in TADS (Tables 1-3). These variables can be grouped into three main categories:

1. Driver characteristics (Table 1): age, gender, and whether the driver was reported to be fatigued (Road and Traffic Authority, 2003), over the speed limit or under the influence of illegal levels of alcohol at the time of the crash, the total number of occupants in the vehicle, and the traffic error the driver might have committed at the time of the crash.

2. Road and environmental conditions (Table 2): rurality (metropolitan/rural), location type/intersection configuration road speed limit, road surface condition, road alignment, traffic signals operating and the natural light at the time of the crash.

3. Vehicle and crash characteristics (Table 3): type and year of manufacture of the vehicle, maneuver of the vehicle during the crash, crash impact type and number of traffic units/vehicles involved in the crash.

Dummy variables were created for all categorical independent variables with more than two categories. Based on previous research, selected interaction terms were also created and modeled. These included interactions between intersection configuration and traffic light control, as well as age and most of the other predictors. Collinearity between independent variables was explored using standard approaches (Kutner, Nachtsheim, Neter, & Li, 2005). None of the variables considered during the model building stage was highly correlated with the other independent variables.

A stepwise multivariate regression modeling procedure was adopted, because this is the most appropriate for prediction studies (Armitage et al, 2002).The analysis began with the smallest equation with all other successive variables, including interaction terms, successively being added to the model. Each predictor was evaluated with respect to how much R^2 would be increased by adding it the model. The predictor which resulted in the highest R^2 increase was added if it met the statistical criterion for entry. The significance level for inclusion in the model was set at 0.15 and was changed to 0.05 at the last stage of the model building. Each time a new predictor was added to the model, each of the variables which had been previously tested were retested to see whether they still contributed significantly to the model; if not, they were dropped from the equation. The procedure continued until all variables which had been added to the model had significant partial regression coefficients, and the inclusion or exclusion of no other variable contributed significantly to the model. All analyses were carried out using SAS, version 8.1 (SAS Institute, 2000).

3. Results

Univariate analyses indicated that driver characteristics, including excessive speed, disobeying traffic control, losing control of the vehicle and other driving errors, were significantly associated with higher severe injury, as measured by the SRR (Table 1).

The analysis also showed that crashes occurring on rural roads and at various intersection configurations (including Y-Junctions, T-Junctions, roundabouts and multiple intersections) were more likely to result in more severe injuries (Table 2). Other road characteristics resulting in a higher risk of severe injury, included curved roads and high speed limit roads including 70-90 km/h and 100 km/h and over.

The number of vehicles involved and the type of crash impact were the only two significant crash characteristics associated with injury severity in older people (Table 3). Single vehicle crashes, with or without impact with an object, were more likely to result in more severe injuries, compared to multiple vehicle crashes, particularly those involving three or more vehicles. Crashes involving a vehicle-to-object incident resulted in more severe injuries than those involving vehicle-to-vehicle incidents.

The multiple linear regression analysis, combining variables from all categories, showed that location type (intersection configuration), rurality, road speed limit, as well as driver characteristics such as driver's error, speeding, and seat belt use, were significant independent predictors of injury severity in older people (Table 4). No vehicle/crash variable was included in the final model. The road location/intersection configuration explained over half of the observed variation in injury severity as explained by the model. In particular, complex intersections such as Y-Junctions, T-Junctions, roundabouts and multiple intersections, more likely to result in severe injuries. None of the interaction terms examined, between intersection and traffic light control, as well as age and most of the other predictors, were significant. The independent contribution of each variable to the final model is shown in Table 4, where the variables are listed according to decreasing contribution.

4. Discussion

The study is unique as it used a database linking hospital discharge data to police crash records and applied recent developments in measuring injury severity to examine the contributions of driver, crash, vehicle and road characteristics to injury severity in older drivers hospitalised as a result of a traffic crash. Rurality, presence of complex intersections, road speed limit, driver's error, speeding and seat belt use were all identified as independent predictors of injury severity.

Our findings indicate that crashes involving older people at complex intersections, notably Y junctions, T junctions, roundabouts and multiple intersections, carry a high risk of severe injury. In fact, crashes occurring at these locations accounted for more variability in injury severity than any of the other variables. While driving in an intersection is a challenging task for all road users regardless of their age, previous research has shown that older drivers are overrepresented in traffic crashes occurring at intersections compared to younger age groups (McGwin & Brown, 1999; Cook, Knight, Olson, Nechodom, & Dean, 2000; National Highway Traffic Safety Administration, 2001). Our findings suggest, in addition to over-involvement of older drivers in crashes occurring at intersections, this age group is also more likely to be severely injured at intersections (compared to other locations), confirming the findings of studies that have indicated an increased risk of a fatal outcome in older people involved in crashes at intersections, particularly at non-controlled intersections (Hakamies-Blomqvist, 1993; Zhang et al, 2000). Interactions between the presence of traffic signals and the intersection configuration were not significant and therefore not included in our final model. This is due to the fact that all traffic crashes occurring at multiple intersections, 96% of crashes occurring at Y junctions, and 81% of crashes at T junctions were uncontrolled (that is, without traffic lights).

The increased risk of injury severity in older drivers involved in traffic crashes at intersections might be explained by reduced physical tolerance to the force of side-impact crashes occurring at these locations (Viano et al, 1990). Previous research has indicated a higher involvement of drivers from this age group in crashes occurring at intersections, particularly complex and multiple ones, which has been mainly attributed to functional deficits frequently associated with aging. Declining visual acuity including peripheral vision, cognitive impairment as well as changes in judgment and attention as a result of the ageing process have been cited as possible factors in older drivers colliding in an intersection with a crossing vehicle, which they did not notice at all, or saw so late that they did not have enough time to try an avoiding maneuver (Shipp & Penchansky, 1995; Isler *et al*, 1997; Caird, Edwards, Creaser, & Horrey, 2005).

Claims have also been made attributing these cognitive and functional deficits to older drivers being over-represented in intersection crashes as “at fault” or the “guilty” party. (Hakamies-Blomqvist, 1996; Zhang et al, 2000;Retting, Weinstein, & Solomon, 2003). Our analysis suggests that driver errors, such as disobeying traffic control and losing control of a vehicle, did have an effect albeit small, on injury severity.

Keskinen, Ota, and Katila (1998), however, challenge these claims in a study exploring normal driving behavior including driving habits and attention patterns of older drivers interacting with younger drivers at T -shaped intersections. Their results showed no differences in attention patterns but differences in driving habits between age groups. Older drivers accelerated more slowly when making the turn, whereas younger drivers approached intersections at a faster rate and this combination made crashes between the two age groups more likely. The authors argued that while older drivers are more likely to be judged the 'at fault' party in intersection crashes, this judgment overlooks the role played by the other 'innocent' party in this type of crash. This calls, according to the authors, for more focus on improving the road environment and developing traffic rules and regulations in such a way that the distinction between' guilty' and 'innocent' becomes less rigid and the road environment becomes more forgiving.

The findings of this study also point to increased injury severity as a result of crashes occurring in rural as opposed to metropolitan areas. Traffic crashes occurring in rural areas were previously found to be more severe and more likely to be fatal than those occurring in urban areas for drivers of all age groups (Boland et al, 2005). Additionally, older drivers, in particular, have been found to be at higher risk of being killed in a traffic crash occurring in rural areas than in urban settings (Clark, 2001). This might reflect the fact that rural drivers continue to drive for more years that their urban counterparts because of low population density and relatively fewer alternative transportation methods in rural areas. This is supported by an American study indicating that older drivers involved in injury crashes in rural areas are 1.8 times as likely as those in urban areas to be impaired by illness or some other physical defect related to the ageing process (Griffin, 2004). There are also claims that driving on rural roads carries a higher risk of injury and death as a result of crash because various rural road users are more likely to speed and drive under the influence of alcohol that those on urban roads (Clark, 2001).

The results also show that excessive speed, as well as driving on roads with higher speed limits, independently increased the likelihood of severe injuries in older drivers hospitalized as a result of a traffic crash. Previous research indicates that while speeding plays a smaller role in older drivers being involved in traffic crashes compared to younger age groups, driving on roads with higher speed limits increased the likelihood of death in older drivers involved in crashes (Cook et al., 2000; Zhang et al, 2000)

Multivariate analysis also showed that lack of seat belt usage independently increased the severity of injury as a result of a traffic crash for older drivers. Seatbelt usage has been shown to reduce the risk of fatality as a result of a traffic crash for all drivers regardless of their age (Be'dard, Guyatt, Stones, & Hirdes, 2002), and non seatbelt usage has also been found to greatly increase the odds of more severe crashes and injuries in all drivers, including older drivers (Kim et al., 1995; Zhang et al, 2000).

Other driver characteristics and behaviors, such as alcohol use, which is known for its effect on increasing the likelihood of involvement in a road crash, were not significantly associated with increased severity in older people hospitalized as a result of a traffic crash. Previous research has indicated that alcohol was less likely to be a factor in traffic crashes involving older adults compared to younger age groups (McGwin & Brown, 1999). Our study found that alcohol does not play a significant role in increasing the severity of injury in older people hospitalized as a result of a traffic crash. Similarly, our study also shows that other driver characteristics such as age group and gender did not have a significant impact on the severity of injury in older drivers who are hospitalized as a result of a traffic crash. These findings mirror those of a study examining factors contributing to the risk of fatality in traffic crashes in older people and which also indicated the insignificance of personal characteristics of age and sex (Zhang et al, 2000).

None of the vehicle/crash characteristics examined in this study remained as independent predictors of injury severity, after adjustment for the other factors. Perhaps vehicle/crash characteristics are important for understanding involvement in traffic crashes but not for injury severity as a result of a crash. It is however important to note that this analysis is limited by the absence of reliable information on airbag deployment and other vehicle safety features which are likely to have an impact on injury severity.

Traditionally, strategies aimed at reducing road trauma in older people have focused on methods aimed at identifying unsafe drivers and enforcing driving cessation. For example, in some states in Australia, drivers reaching a specified age are required to prove their fitness to drive through medical assessment and/or on-road testing (Fildes, 1997). Recent research indicated that these policies have not had any tangible road safety benefits (Langford, Fitzharris, Koppel, & Newstead, 2004). Driving cessation has also been associated with an increase in depressive symptoms and feelings of isolation in older people (Marottoli et al., 1997). This is directly related to the fact that in Australia and other industrialized nations such as the United States, older people rely on driving as their method of transportation in the absence of suitable alternatives particularly in rural and remote areas.

Due to the limitations of some of the traffic safety strategies specifically aimed at older drivers, including driving cessation programs, there has been a shift towards adopting a more encompassing prevention model that puts greater emphasis on improving vehicle and environmental conditions (Wang et al, 2004). The findings of this study, which seem to point the importance of environmental factors, support this approach. In addition to improvements in the areas of highway geometry, operations, and traffic control devices particularly at complex intersections and roadway curvatures, other proposed improvements to the road environment that may improve older driver safety include increased sign luminance, increased reflectivity of roadway markings, larger sign symbols and appropriate placement of signs (Staplin et al., 2001). These changes to road and traffic system are likely to have the added benefit of also being able to meet the needs of all road users.

It is important to note that the predictors of injury severity found in this study accounted for only 14% of the variation in injury severity. This might be due the nature of injury severity measure used in this study. While the SRRs were based on Australian data, the approach is limited by only including hospital deaths. Adding deaths occurring outside hospital would enhance the value of the severity estimates in the future (Meredith et al., 2002). Nevertheless, we believe that the severity measure used in this study is a great improvement on the severity indicators usually found in police crash records.

The low observed variability in injury severity might be related to the fact that other factors such as existing medical conditions, use of some type of medications (McGwin, Sims, Pulley, & Roseman, 2000), and other variables such as judgment and emotional instability at the time of the crash, (Hakamies-Blomqvist, 1998), could not be taken into account in this study as the information was not available. Sample size also had an impact on the variability in injury severity. When grouping various categories within each variable, some categories with significantly different means in the average SRR had to be grouped together because of small counts. An example of this is the grouping of T and Y intersection types in the same category. Record linkage of hospital and police crash records of more than one year, ideally 3 to 5 years, will go a long way in increasing the sample size and better exploring the factors influencing injury severity, particularly in older drivers.

It is important to note that for variables related to alcohol intake, speeding and seat belt use, unknown values were grouped together with 'No' category. It is very difficult to assess the impact of this on the findings as the proportion of missing values for these variables is not known.

Finally, while the necessary steps were taken to ensure an accurate linked dataset, data record linkage involves trade-offs between the number of false positives or non-matches and false negatives or missed matches. The inclusion of these cases, in particular false negatives, in the final dataset is inevitable as the strategy we adopted aimed at maintaining high specificity. However, previous studies have shown that probabilistic record linkage techniques, such as those used in this study, result in high quality outcomes with very low error rate (Rosman & Knuiman, 1994).

5. Conclusions

The multiple linear regression analysis showed that road type, the presence of complex intersections, road speed limit as well as driver's error, speeding and use of seat belt were significant predictors of injury severity in older people hospitalized as a result of a traffic crash. Complex intersections, in particular, appear to have the greatest impact on injury severity indicating that older drivers are not only overrepresented in traffic crashes occurring at intersections, as previous research has demonstrated, but that they are also more likely to be severely injured in complex and challenging intersections.

The importance of crashes occurring at some intersection types suggests that environmental modifications might contribute to a decrease in the severity of injury as a result of road crashes. With the ageing of the population, a greater number of older people will be driving on roads that were originally designed without the specific needs of older road users in mind. In addition to programs aimed at monitoring older peoples' capacity to drive, changes to the road and traffic environment are required to accommodate this significant demographic challenge. An example of environmental modifications could include the installation of traffic control devices or four-way stop signs at complex intersections. Other improvements to road environment that have been suggested to improve older driver safety include increased sign luminance, increased reflectivity of road markings, larger sign symbols and better positioning of traffic signs. These changes are likely to be beneficial to drivers of all ages.

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