Compared characteristics of 2000-2007 single vehicle rollover fatalities in three Australian states from the Australian National Coroners Information System (NCIS) database

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Abstract

A three-level analysis of 2000-2007 single vehicle rollover fatalities in three Australian states was carried out using NCIS data. Successive selection criteria were applied to the initial dataset to analyse:
- Occupant fatalities in single passenger car crashes (1743 cases),
- Occupant fatalities in single passenger car rollovers (475 cases),
- Injuries to contained occupant fatalities in single passenger car rollovers (209 cases).

Results showed strong disparities between NSW, NT and VIC in terms of crash type distribution and containment of the occupant. Differences were also found in rollover initiation, speed at initiation, number of turns, and secondary impact. Overall, the strongest association of fatal neck/thoracic spine injuries with head injuries was found for the contained, belted occupant.

This analysis of single vehicle rollover fatalities is consistent with previous findings. In Australia, strategies for rollover injury risk mitigation will specifically need to take into account a broad range of characteristics to be effective.

Keywords

Vehicle Safety, Rollover, Descriptive statistics, Injury assessment

Introduction

In Australia, based on 2005 data, in about 1 in every 3 vehicle fatalities the vehicle was found to have rolled over [5]. One occupant safety priority in these events is to prevent partial or total occupant ejection [9]. There is also a need to improve occupant protection within the vehicle, as contacts between the occupant’s head and the vehicle’s interior are associated with a high risk of brain, skull, face and neck injury [1]. Due to the complex nature of rollover crashes, it has not been possible so far to define a criterion suitable for the evaluation of the severity of neck injuries to the contained occupant. As there are very few real-world data available, there is a need to describe the possible cause (eg. loading mode), nature (level, type, severity...) and distribution of head and neck injuries in these specific Motor Vehicle Accidents (MVAs). In particular, there is a need to assess how representative the injury mechanisms assessed using Post-Mortem Human Subjects (PMHS) in simulated experimental conditions are of the real events [4].

An analysis of single vehicle rollover fatalities was performed using data available from the Australian NCIS database. Its end aim was an in-depth assessment of head and neck injuries sustained by contained occupants in such fatal events. This paper presents the protocol used in a staged three level analysis of the NCIS data and the results from the first two stages: lower and middle level analyses.

Methods

A protocol was designed to search the NCIS database, with the aim of selecting relevant cases for an in depth analysis of head and neck injuries in single vehicle rollovers. Ethics approval for the study was obtained from the Victorian Department of Justice Research Ethics Committee (Reference No. EC/06/29). The associated NCIS query was performed in March 2008 and subsequently updated until the
29th of January 2009. The query was designed to access and retrieve the NCIS records of all closed fatality cases coded as Transport Injury Events (TIE), from all Australian States and Territories, for events having occurred between 01/01/2000 and 31/12/2007. The resulting database consisted of a spreadsheet containing a coding of each available descriptor/field for each fatality case. Relevant fields used in this study included: age, sex, case type completion, intent completion, medical causes of death, primary, secondary and tertiary mechanisms of death, object type and description causing death, mode of transport type and description, user code, counterpart type and description, context, and location. The subsequent analyses, carried out at three different levels, were performed by applying successive control and selection criteria to this initial dataset, which was finally restricted to relevant rollover cases for the in-depth injury analysis. The following paragraphs describe this process.

**Lower-level analysis:** A lower level statistical analysis of the data was first performed. It aimed at presenting a picture of Australian rollover fatalities within its single vehicle MVA fatalities subgroup. In particular, the analysis aimed at comparing the incidence of rollover fatalities between Australian states. The initial 9717 TIE cases that had been retrieved from the NCIS were first restricted to all fatalities to vehicle occupants involved in a single vehicle passenger car crash by applying successive selection criteria (Figure 1). The lower level analysis was then carried out on the subsample consisting of the New South Wales (NSW, 753 cases), Northern Territory (NT, 169 cases) and Victorian (VIC, 821 cases) cases. These three states had been chosen based on a preliminary study [6] that allowed assessing the availability and the quality of documents attached to the cases, both online and as manual files at coroners courts. For these 1743 cases, all documents (police report/narrative, inquest/coroner’s findings and autopsy reports) that were available as online attachments were retrieved and checked to classify the crash mode. Crashes were classified as: “frontal”, “side”, “frontal/side”, “rear-end”, “rollover (primary)”, “rollover (likely to be secondary)”, “multiple”, “other”, “not relevant/unknown”. Incidents were defined as rollovers according to the NASS-Crashworthiness Data System (CDS) guidelines [10]. At this level, the list included child and infant fatalities. Descriptive statistics were then used to present these data and evaluate their quality.

**Middle-level analysis:** A middle-level analysis was carried out, focusing on the description of the single vehicle rollover cases that had been identified in the lower level analysis. At this stage infants and children (either up to the age of 8 years or seated in a booster – based on RTA guidelines) were excluded. Table 1 presents the associated case summary.

<table>
<thead>
<tr>
<th></th>
<th>NSW</th>
<th>NT</th>
<th>VIC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>152</td>
<td>126</td>
<td>197</td>
<td></td>
<td>475</td>
</tr>
</tbody>
</table>

Secondary rollovers excluded, age< 8 yrs excluded

The NASS-CDS guidelines were adhered to for coding of the rollover event, including the initiation phase, number of ¼ turns, speed at initiation. Descriptive statistics and analysis of these fields were performed and collated. For the 475 cases each contributor to the Cause of Death (COD), as identified and coded by the forensic examiner in the NCIS database, was assigned one of the following segments: Head, neck, spine, chest, abdomen, upper limb, lower limb. Basilar skull fractures were coded as neck injuries, as this injury mechanism had been shown to relate to the loading of the neck for the purpose of neck injury risk assessment [8]. “Contained” or “ejected” occupants were coded for cases where this fact was specifically reported in either Police report, Coroner’s findings or Autopsy reports. A similar selection was applied to code the “seatbelt worn/not worn” fields.

**Upper level/In-depth analysis:** A specific interest of the analysis was to be able to compare neck injury patterns to the contained occupant in single vehicle rollovers, first with injury patterns from in-plane events (eg. frontal or side impacts) and second with experimentally produced injuries, both in in-plane reconstructions as well as in inverted drop-tests. The association between head and neck injuries and their comparison to other impact events, eg. shallow water diving injuries, was also of interest. Finally, for head and spinal injuries, the location of the head impact (if identified), including its possible laterisation from the sagittal plane was coded.
In some cases, even though the incident was a single vehicle impact, it was not clear whether the overturning event was secondary to the injuries sustained. Therefore, at a first level, cases with impacts prior to (not directly responsible for) the initiation had been classified as multiple impact events. Further, for the in-depth analysis, to assess the injury patterns associated with “pure” rollovers, cases where an identified impact occurred at any time other than (not directly responsible for) the initiation were further discarded. This selection resulted in a final relevant dataset of 209 fatalities of contained (including likely to be contained) occupants in “pure” single-vehicle rollovers from NSW, NT and Victoria. Finally, from these 209 cases, all autopsy reports that were not available online were retrieved from their respective State Coroner’s Office. For each case, each injury was identified and coded using the Abbreviated Injury Scale (AIS). The MAIS is the most severe injury code in a patient with multiple injuries. To assess the contribution of each segment, MAIS values were assessed for the following segments: Skull/face, Brain, Neck, Chest, Abdomen, Pelvis, Upper limb, Lower limb. At the date of writing of this paper, only 37 cases had been fully analysed and coded for injury and results are only presented for the lower and middle level analyses.

**Results**

**Lower level analysis**: Figure 2 presents the distribution of the 1743 single vehicle fatalities by crash type. The overall distribution of single vehicle rollover fatalities agrees with similar studies [9]. There are differences between the three states during the study period (Figure 3) with single vehicle rollovers accounting for 27% of all single vehicle fatalities in Victoria up to to 78% in the NT.
Figure 2: Distribution of crash type associated with a single vehicle fatality event (NSW, NT, VIC 2000-2007, 1743 single vehicle event fatalities), excluding unknowns.

Figure 3: Single vehicle rollover fatalities as a percentage of all single vehicle fatalities, including lower and upper boundary error bars, based on each states’ unknown cases (lower bound = assuming none of the unknown cases is a rollover; upper bound = assuming all unknown cases are rollovers).

Figure 4 presents the percentage of single rollover fatalities where the rollover event was secondary to another identified crash type, relative to all single vehicle fatalities where the vehicle rolled over.

Figure 4: Single vehicle secondary rollover fatalities as a percentage of all single vehicle fatalities where the vehicle rolled over.
**Middle level analysis:** Figure 5 presents a distribution of the segment injuries identified as COD, for three groups of occupants involved in a fatal single vehicle rollover. The global distributions (all single vehicle rollover fatalities) agree with similar studies [2, 5], and the results confirm that there is a higher proportion of spinal and neck injuries contributing to the COD when the occupant is both contained and belted compared to ejected occupants. Results also confirm that the frequency of multi-segmental COD is higher for ejected occupants (68% of the cases) than for contained, belted occupants (41% of the cases). At this middle level, disparities between NSW, NT and VIC in terms of containment of the occupant (Figure 6) or rollover initiation (Figure 7) were observed.

![Figure 5: Frequency of segment injury described as COD, per 100 COD, for 475 single vehicle rollover fatalities (173 ejected occupants, 69 contained and belted)](image)

**Figure 5:** Frequency of segment injury described as COD, per 100 COD, for 475 single vehicle rollover fatalities (173 ejected occupants, 69 contained and belted)

![Figure 6: Percentage of contained/likely to be contained/partial and ejected fatal single vehicle rollover cases relative to all single vehicle fatalities.](image)

**Figure 6:** Percentage of contained/likely to be contained/partial and ejected fatal single vehicle rollover cases relative to all single vehicle fatalities.

![Figure 7: Rollover initiation type according to NASS-CDS, as a percentage of all initiations, for all three states, 2000-2007.](image)

**Figure 7:** Rollover initiation type according to NASS-CDS, as a percentage of all initiations, for all three states, 2000-2007.
Discussion and conclusion

A protocol for analysing Australian single vehicle rollovers is presented. It was applied to available NCIS data for the years 2000 to 2007 in three Australian states. The following paragraphs discuss some limitations and conclusions that can be derived from the associated results.

The first limitation, at this stage, is the restriction of the study to the analysis of three states only. The rationale for this selection was the in-depth analysis and the identified need to access both police reports and autopsy reports. Based on previous work related to this research project [6], the rate of online availability of documents (including autopsy reports) and the feasibility of obtaining missing documents directly from the State Coroners’ Offices has so far precluded the authors from investigating other states. Despite this selection, and as the NCIS database is being gradually updated, there were still many documents missing online, as shown for example by the large error bars in Figure 3.

In terms of the quality of the documents, in Victoria, there was a good online complementarity of police reports and inquest findings, allowing for a good characterisation of the crash event.

In NSW, much information was missing online; in particular, most police reports were not available online from 2004 onward. Police reports were generally more detailed on their own than for Victoria or NT states. Containment or ejection were generally specifically reported but other information, such as seatbelt use, was generally missing.

In NT, there was a very good online availability of all documents (95% availability rate of both police reports and autopsy reports). Police reports were succinct but well complemented with very detailed findings.

As a general rule, risk of false positives is estimated to be low due to the conservative approach taken. This would have restricted the number of cases for the in-depth analysis, but would have increased the quality of the analysis. Conversely, risk of false negatives is estimated to be important, as many cases were discarded through the selection due to lack of information.

**Lower level analysis:** As explained above, the missing NSW cases resulted in 21% of the single vehicle occupant fatalities being associated with an unknown single vehicle MVA type for this state, which is a potential bias. Despite this limitation, the distribution compares well with results by Summers et al [9] in the USA, who reported that, in 2003, rollovers accounted for 33% of all passenger vehicle occupant fatalities.

**Middle level analysis:** At this level, the main issue concerned the coding of seatbelt use, for which a description was missing in most cases. Even when its usage was specifically described, some degree of uncertainty remained. Therefore, this parameter should not be used a selection criterion if possible. According to US NCAC and FARS (Fatality Analysis Reporting System), the percentage of restraint use was consistently 45% (55%: not used) during the years 2004 and 2005 in the USA [9]. In Australia, a high seatbelt use rate had been previously reported [3].

In terms of rollover initiation, the high number of Trip, Turn, Fall and lateral Bounce cases confirms the importance of the lateral direction component (as opposed to end-over-end or other modes of rollover) in this crash type.

In the course of checking, the authors became aware of many cases with possible similarities between rollovers and side impact, eg. found many cases where the vehicle impacted sideways into a tree, forcing the roof to collapse and trap the occupant.

Finally, the body segment COD distribution compares well with results presented previously [7], and to the AIS5+ distribution of injuries reported by Digges et al. [2]. In particular, our results are consistent with other studies, in finding that there is an increase in the proportion of critical to fatal spine injuries with belt use for contained occupants. Despite having a lower overall risk of fatal injury than ejected and/or unrestrained occupants, the belt restrained occupant is still at risk of injuries leading to death or severe impairment. The study reinforces the need to improve occupant protection through preventing rollover events and minimising the impact loading of the occupants through improved crashworthy design and occupant restraint systems.

**Upper level/in-depth analysis:** Retrieving the missing online autopsy reports from the respective State Coroner’s Offices proved to be a lengthy and tedious process. Only a fraction of these documents have been analysed and coded so far and for this reason, no results summaries have been presented above. The analysis of the autopsy reports and the comparison of the results with e.g. clinical or experimental studies also requires a thorough discussion on its own, which will be presented in an upcoming article. At this stage, the preliminary results present a significant proportion of basal skull fractures (6 out of 37 cases) and also show both contiguous and non-contiguous cervical spinal injury patterns. Both these injury...
characteristics will be further investigated, particularly in relation to previous work describing neck injury mechanisms in experimental inverted cadaveric drop-tests [8], in relation to neck loading.

To conclude, this analysis of single vehicle rollover fatalities is consistent with previous findings in terms of its main features (i.e. when combining results from all three states). At the two levels that are presented here, it confirms some strong disparities between the NT and NSW, and Victorian states; in Australia, any strategies for rollover injury risk mitigation will specifically need to take into account this broad range of different characteristics in order to be effective.

Although the quality of the data available through the NCIS is good, obtaining extensive, detailed information, in particular detailed description of the injuries, from the database is a difficult process. At the level of the incident description, it is expected that data quality would benefit from the implementation of a new National Police Form.

Acknowledgements

The authors would like to thank the Australian Research Council for providing funds to carry out this research through the Discovery Projects grants scheme (No: DP0663834). The authors would like to also thank the Victorian Institute of Forensic Medicine as the source organisation of the National Coroners Information System from which rollover crash data was extracted for the statistical analysis presented in this paper.

References