Estimating factors influencing hospitalisation over 14 days among compensated road crash injuries in Victoria

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Transport Accident Commission (TAC)

Abstract

Background: The Transport Accident Commission's (TAC) data on hospitalised road trauma is a consistent measure of injury severity in Victoria. Hospitalisation over 14 days, a potential indicator of severe injury, composes 6 per cent of total TAC claims, but almost two-thirds of TAC compensation costs. Aim: This study attempted to estimate factors impacting the likelihood of a TAC claim involving a hospital stay of over 14 days. Data: All the hospitalised TAC claims where the crash had occurred in 2010 were used (4,094 claims; 19.9 per cent were hospitalised for over 14 days). Data on road user, vehicle, road, and crash characteristics of each claim were extracted and used as explanatory variables. Method: A binary logistic regression model was developed to estimate the impact of the explanatory variables on the likelihood of hospitalisation over 14 days. Results: Vulnerable road users, particularly motorcyclists and pedestrians, the elderly (65+), older than 10 years vehicles' occupants, claimants who involved in crashes on high-speed roads, claimants who sustained serious injuries and claimants sustained psychological trauma as well as physical injuries were more likely to be hospitalised for over 14 days. Conclusions: The findings of this research provide the necessary evidence to speculate about underlying causality and tailor-made strategies to address the risk of severe injury in Victoria.

Introduction

Road traffic injuries are a major but neglected public health problem (WHO 2013). It is projected that if concerted efforts for effective and sustainable prevention are not taken, road traffic injuries will be the fifth leading cause of death by 2030 (WHO 2013). Understanding factors that increase the risk of serious injuries in road crashes is key to identify/develop more effective road safety interventions.

The Transport Accident Commission (TAC), the statutory insurer of third-party personal liability for road crashes in the State of Victoria, deals with thousands of injured Victorians, covering the whole spectrum of injury from death to superficial of injuries. Two of the objectives of the TAC, stated in the Transport Accident Act (1986), are (1) "to ensure that the transport accident scheme emphasises accident prevention and effective rehabilitation," and (2) "to perform its functions and exercise its powers effectively, efficiently and economically" (Transport Accident ACT 1986; Page 34). In order to achieve these objectives, the TAC has developed Key Performance Indicators (KPIs) to monitor and evaluate the effectiveness of its injury prevention programs, and ensure that the scheme is viable, sustainable and represents value for money. The number of 'hospitalised over 14 days' claims is one of these KPIs. There are two main reasons why the number of 'hospitalised over 14 days' claims has been chosen as a KPI. Firstly, it has been shown that the TAC claims data, e.g. hospital admissions and length of hospital stay, provide consistent measures of serious injury for use in road safety performance monitoring and road safety research (Hoareau et al. 2007). In addition to that, from 2011 onwards, TAC hospital admissions data is used as the measure of 'serious injury' in the Macro Estimates for Target Setting (METS) model developed for road safety strategy setting in Victoria.

Secondly, hospital admissions over 14 days (HOSP15+) compose a significant part of the total TAC compensation costs. The analysis of TAC claims data between 2000 and 2012 shows that while

HOSP15+ claims compose only 6 per cent of TAC claims, they make up over two-thirds of the total compensation costs. Therefore, the TAC closely monitors the number of HOSP15+ claims as one of its most important Key Performance Indicators (KPIs).

Aim

Considering the importance of monitoring and reducing the number of 'hospitalised over 14 days' claims for the TAC to achieve its statutory objectives, this research investigates what factors impact the probability of a claim involving hospital admissions for over 14 days. The findings of this research are believed to help the TAC hone its public awareness campaigns and road safety improvement investments.

Study design

All hospitalised TAC claims in the TAC claims database (a total of 4,094) where the crash had occurred in 2010 were included in the analysis. A binary variable was defined to represent the hospitalisation status of each claimant, with '1' indicating HOSP15+ claims and '0' indicating hospitalised claims for 14 days or less. This variable was used as the dependent variable (DV).

In terms of independent variables (IVs), it was of interest to investigate what road user, vehicle, road, crash circumstance and injury severity factors would influence the likelihood of HOSP15+. Determining influential factors could help the TAC hone its road safety awareness campaigns and interventions by targeting these factors and achieve better safety results. Table 1 shows the list of independent variables used for this research.

Table 1. Independent variables

Variable Category	Independent Variables	
Road User	- Type - Age - Gender	- Licence type - Seat belt/Helmet wearing
Vehicle	- Vehicle type - Year of manufacture	
Road	- Posted Speed - Straight/curve - Divided/undivided	- Road geometry (intersection/not) - Urban/Rural
Crash Circumstances	- Crash type (Definitions for Classifying Accidents Codes) - Time/Day of week - Vehicle movement	- Light conditions - Atmospheric conditions - Hit-and-run
Injury Severity	- Maximum Abbreviated Injury Scale (MAIS)	- Psychological trauma

With regards to 'Road User' factors, the data on the type of road user (Driver; Passenger; Motorcyclist; Cyclist; Pedestrian), their age and gender, their use of seatbelt/helmet (if applicable), and the type of license they held at the time of the crash (if applicable) were collected.

For vehicle factors, the type of vehicle and the year of manufacture were used.

The posted speed, the horizontal alignment of the road (straight or curve), the division of the road, road geometry (intersection or not at intersection) and the urbanisation level (urban or rural) were used to represent road factors.

With regards to the circumstances of the crash, the Definitions for Classifying Accidents (DCA) codes, time and day of crash, the movement of the vehicle, light and atmospheric conditions and the incidence of hit-and-run were used.

Injury severity is an important compounding factor of the length of hospital stay (Peek-Asa et al. 2011; Santolino et al. 2012). In 2012, the European Union adopted the Maximum Abbreviated Injury Scale (MAIS), which is a threat-to-life measure of injury severity, as an interim indicator of "Serious Injury" (the European Commission's High Level Group on Road Safety). An MAIS greater than or equal to three (MAIS >= 3) was decided to be categorised as "Serious Injury." The same injury severity measure is used for this research to represent injury severity. In addition, the influence of psychological trauma on the likelihood of HOSP15+ was investigated by including a variable flagging such trauma.

Data build

The necessary data for this research were gleaned from a few different sources, namely:

- VicRoads: Registration and Licensing (RandL) & Road Crash Information System (RCIS) data sets
- Victoria Police Accident Reporting System (VPARS): police crash data
- TAC: claims, and injury data
- Monash University Accident Research Centre (MUARC): injury data

- Department of Health and medical providers

Briefly, each claimant's information was extracted from the TAC claims dataset. The associated crash data, provided by the Victoria Police through the VPARS dataset, were added, including data on crash type, location details, type of location, road geometry and speed zone and climatic conditions. Afterwards, the data on the severity of injuries sustained by the claimant were collected from the TAC datasets, complemented by some additional analyses conducted by the Monash University Accident Research Centre (MUARC) to compute MAIS scores. Figure 1 shows the data build process. It should be noted that no personally identifiable information was included in the research.

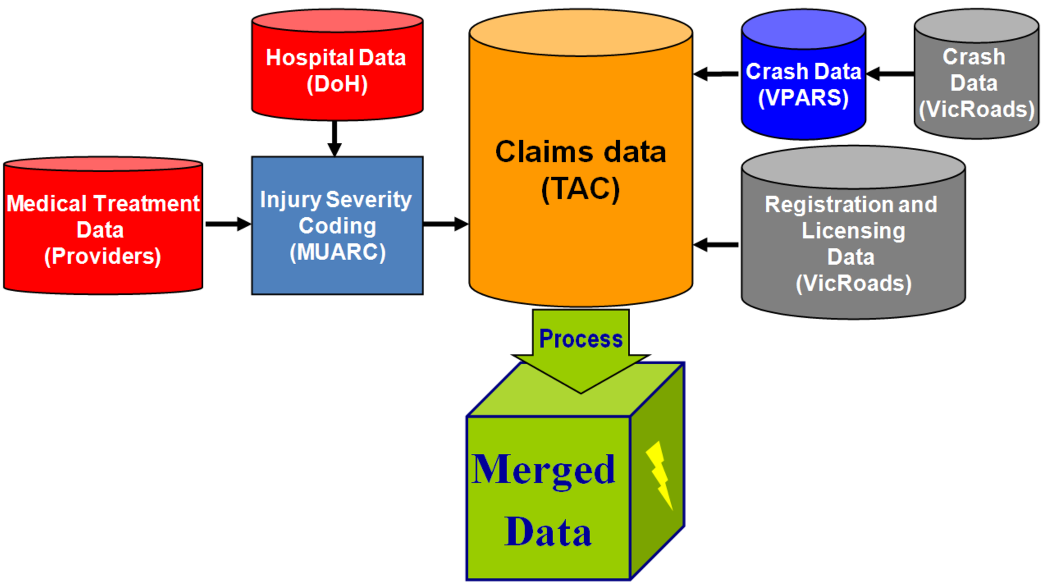

Figure 1. Data build process

Modelling method

Binary logistic regression is commonly used to predict the probability of a binary discrete outcome from a set of predictor variables. As the injury outcome variables chosen for this study are of a binary nature (HOSP15+ vs. hospitalisation claims for 14 days or less), the binary logistic regression technique was used.

The SPSS software package (version 20) was used to construct the logistic regression model.

Model building process

In order to construct the best model, it was essential to design a systematic procedure to select the most parsimonious subset of independent variables that satisfactorily explained the variation in the binary dependent variable. The backward elimination logistic regression procedure was employed. The procedure involves starting with all the variables in the model, testing the effect of removing of each independent variable (one-by-one, by using a model comparison criterion) and removing a variable only if its removal did not significantly deteriorates the model's fit. The process is repeated until no further variable can be removed from the model. The log-likelihood ratio statistics were used as the 'model comparison criterion.' A p-value of 0.05 was chosen as the removal level.

Goodness of fit

After building the logistic regression model, the model's fit was assessed. The Hosmer-Lemshow test, a deciles-of-risk based chi-squared statistic, was used to evaluate the fit of the model. When the Hosmer-Lemshow statistic is significant, the null hypothesis that the logistic model sufficiently describes the dependent variable is rejected (Tabachnik and Fidell 2001).

In addition to checking the Hosmer-Lemshow statistics, it is sometimes useful to check the ability of the model to classify or correctly predict the binary injury outcomes (predictive power). This is commonly done by computing the area under the receiver operating characteristics curve. A receiver operating characteristics curve is a graphical plot which illustrates the performance of a binary classification system as its discrimination threshold is varied.

It should be noted that the relevance of predictive power depends on the intended purpose of the model. If the model is constructed to identify factors associated with the outcome, predictive power is not of vital importance. However, lack of fit can be a problem by indicating that some key confounding variables might have been left out of the model. In this research, the modeling was designed to ascertain the association of IVs and the response variable and therefore, the predictive power of the model was not considered to be the most critical aspect of the fitted models.

Importance of the predictors

The influence of each predictor on the likelihood of HOSP15+ is assessed through calculating its odds ratio. The odds ratio for a categorical variable relative to the reference category defined from that variable is given by:

odds ratio = $\exp(B_j)$ Eq. 9.8

The odds ratio, for example, is the increase or decrease in odds of a male claimant being hospitalised over 14 days compared to a female claimant, in the case of "female" being the reference level of the gender categorical variable. An odds ratio greater than '1' denotes an increase in the odds of HOSP15+ in the category of interest relative to the reference category and vice versa.

Results

As discussed in the prior section, a binary logistic regression model was developed to estimate the odds of a TAC claim involving a hospital stay of over 14 days. The results of the Hosmer-Lemshow test show that the model sufficiently describes the dependent variable (Chi-square: 11.788; p-value: 0.161). The model also possesses an acceptable predictive power (area under the receiver operating characteristic curve = .618; 95% CI .594-.641). However, as the model is to identify associated factors with the outcome, the predictive power of the model is not too crucial.

Table 2 presents the outputs of the model, showing the correlates of HOSP15+ claims, and their respective coefficients, Standard Errors (SE), Wald statistics and odds ratio.

Table 2. The outputs of the model

	Variables	Attributes	B	S.E.	Wald	df	Sig.	Exp(B)	EXP(B) – 95% CI	
									Lower	Upper
Road User	Type				59.14	6	< .001			
		Passenger	-0.06	0.13	0.25	1	0.616	0.93	0.72	1.21
		Motorcyclist	0.89	0.13	47.25	1	< .001	2.45	1.9	3.16
		Cyclist	0.17	0.22	0.64	1	0.423	1.19	0.78	1.82
		Pedestrian	0.66	0.22	8.71	1	< .01	1.93	1.25	3
		Ref. Driver								
	Age Group				162.4	4	< .001			
		15-24	1.00	0.34	8.56	1	< .01	2.74	1.4	5.39
		25-44	0.92	0.34	7.2	1	< .01	2.51	1.28	4.93
		45-64	1.08	0.34	9.88	1	< .01	2.96	1.50	5.81
		65+	2.34	0.34	46.55	1	< .001	10.44	5.32	20.5
		Ref. 0-14								
Vehicle	Manufacture Year				7.41	2	< .05			
		2000-	0.23	0.11	4.8	1	< .05	1.26	1.02	1.56
		Ref. 2001+								
Road	Posted Speed				16.61	3	< .001			
		60-70 km/h	0.20	0.13	2.43	1	0.119	1.23	0.95	1.59
		75-110 km/h	0.41	0.14	9.37	1	< .01	1.52	1.16	1.99
		Ref. <= 50 km/h								
Injury Severity	MAIS				236.88	2	< .001			
		>= 3	1.62	0.11	236.73	1	< .001	5.1	4.14	6.27
		Ref. <= 2								
	MAIS for head/neck				27.56	1	< .001			
		>= 3	0.72	0.14	27.56	1	< .001	2.06	1.57	2.70
		Ref. <= 2								
	Psychological Trauma	Yes	1.39	0.16	81.08	1	< .001	4.03	2.97	5.45

As can be seen, type and age-group of claimants, the year of manufacture of the vehicle, the posted speed of the road, and the severity of the injury (MAIS and MAIS for head/neck parts) were the explanatory variables associated with the outcome variable (HOSP15+).

With regards to the importance of the attributes of the road user type variable, compared to the reference attribute (drivers), motorcyclists (2.45 times), pedestrians (1.93 times) and cyclist (1.19 times) had a higher likelihood to be HOSP15+. In comparison to 0-14 year olds, 65+ (10.44 times), 45-64 (2.96 times), 15-24 (2.74 times) and 25-44 (2.51 times) were more likely to be HOSP15+.

Vehicles that were manufactured before 2001 were 1.26 times more likely to be associated with HOSP15+ than those manufactured between 2001 and 2010.

The likelihood of HOSP15+ increased with the posted speed, with claimants being more likely to be hospitalised for over 14 days when involved in crashes in 75-110 km/h (1.52 times) and 60-70 km/h (1.23 times) zones than in <= 50 km/h zones.

With regards to the MAIS scores, compared to those injuries categorised as minor injuries (MAIS2-), claimants sustaining serious injury (MAIS3+) were 5.1 times more likely to be HOSP15+. Controlling for MAIS, it was found that serious head/neck injuries (MAIS for head/neck parts being over 2) were also almost two times more likely to be HOSP15+.

Finally, claimants who showed symptoms of psychological trauma due to the crash were almost four times more likely to be HOSP15+ compared to those who did not.

Discussions

The findings of the modelling process and the implications of these findings for the TAC policy making are discussed in this section. First, the findings of the model are discussed under the general type of independent variables presented in Table 2.

Road User correlates of HOSP15+ claims

As can be seen in Table 2, the age and road user type of claimants are associated with the probability of the claimant stay in the hospital for over 14 days. The 65+ age group were found to have a significantly higher chance of HOSP15+, followed by 45-64 and 25-44 age-groups, respectively. For instance, compared to the reference age-group (0-14), the 65+ age-group are over 10 times more likely to stay in the hospital for over 14 days (95% CI: 5.32-20.5). This might reflect the physical frailty of this age-group, and their propensity to sustain more severe injury as the result of the crash and require a longer recuperation time in the hospital. It should be noted that while the Maximum Abbreviated Injury Scale (MAIS) scores were used in the modelling process to capture the impact of injury severity on the probability of HOSP15+, the MAIS score may not fully represent the threat-to-life injury outcomes of road crashes. Therefore, for some of the identified correlate, their association with HOSP15+ is discussed in the light of their potential impact on crash injury severity. This finding is an important one, considering the population ageing phenomenon in Australia. According to the Australian Bureau of Statistics (ABS), while the percentage of 65+ age-group was under 15 per cent in 2010, this percentage will rise to almost 25 per cent in 2050.

Vulnerable road users were found to be highly likely to stay in hospital for over 14 days. Motorcyclist claimants were the most likely group to be HOSP15+, followed by pedestrians and cyclists. Considering that it was attempted to control for injury severity by including the MAIS scores, this finding might shed light on the insufficiency of the MAIS score to represent injury severity and/or other characteristics of vulnerable road users' crashes other than injury severity influence their length of hospital stay. Further research is needed to investigate those potential contributors to HOSP15+ other than injury severity represented by the MAIS.

Vehicle correlates of HOSP15+ claims

Year of manufacture of the vehicle involved in the crash (in the case of multiple-vehicle crashes, the vehicle of the injured party was used) was revealed to be associated to HOSP15+, with the vehicles older than 10 years being more likely to be associated with HOSP15+ (1.26 times; 95% CI: 1.02-1.56). It is likely that this is because newer vehicles are more crashworthy and/or newer designs perform better in preventing those injuries that result in long hospital stays.

Road correlates of HOSP15+ claims

Speed has been found to have a very large effect on road safety, probably larger than any other known risk factor (Elvik et al. 2004). The findings of this research show that speed is also likely to be highly associated with long hospital stays.

Injury correlates of HOSP15+ claims

The findings of this research showed that the claimants scoring higher in the MAIS injury scale were more likely to be HOSP15+. The MAIS is a threat-to-life measure of injury severity. This is an intuitive finding as it is expected for the more seriously injured claimants to be hospitalised for a longer time. The other interesting finding is that those claimants that had a higher MAIS score for their head/neck body areas were more likely to be HOSP15+. Considering that the general injury severity was controlled for by including the overall MAIS score, this finding might underline the yet to be validated hypothesis that head/neck injuries are more serious than other body parts injuries with the same MAIS score. This hypothesis should be tested in future studies.

Those claims that involved psychological injuries as well were also more likely to involve HOSP15+. This may indicate that the mental state of the claimant and their psychological reactions to the crash impacts their health state, and consequently, length of hospital stay.

What does it all mean for the TAC?

The findings of this research point to a number of groups and issues of key importance to the TAC to inform the TAC's road safety awareness campaigns and interventions, namely:

- Vulnerable road users, particularly motorcyclists and pedestrians
- The elderly (65+)
- Older than 10 years vehicles
- High-speed roads
- Serious Injury
- Psychological trauma

The TAC has historically concentrated its road safety efforts on vulnerable road users and the elderly, and has programs that address high speed roads and the vehicle fleet. The TAC has been working closely with its road safety partners, i.e. Vicroads, Victoria Police and Department of

Justice, to enhance the safety of the above-mentioned groups. The findings of this research confirm and support the TAC's continual focus on these areas.

However, it should be noted that sociodemographic and travel patterns in Victoria are lilkely to change in the coming decade. More pedestrians and cyclists will be using the roads as walking and cycling are promoted, and more people are likely to take up riding motorcycles as a cheaper, more convenient alternative to private cars in crowded urban areas. A higher percentage of population will be over 65 years as the populating ageing continues in the coming decades. Serious Injury also warrants further attention. It is argued that the Serious Injury problem is not well-understood and its magnitude is under-estimated. As it is shown by this research that more seriously injured claimants are more likely to be HOSP15+, it is important for the TAC to investigate the Serious Injury problem more rigorously in order to better understand underlying causes so it can develop more effective, sustainable prevention measures. Further research is warranted to better understand the association of psychological trauma and length of hospital stay.

Conclusions

There are some limitations that should be conceded. Firstly, previous studies have shown that length of hospital stay depends on a variety of factors including but not limited to, operational factors such as changes in service delivery over time, type of injury and injury complications, type of medical insurance, socioeconomic factors, and precrash claimant characteristics such as health and functional status and drinking/smoking habits (BuSaba and Schaumberg 2007; Arango-Lasprilla et al. 2010; Cryer et al. 2010; Santolino et al. 2012; Osler et al. 2013). Data on these factors were not available to this research and are suggested to be included in future research. It should be noted that while the focus of the TAC road safety programs is on pre-crash and crash stages, controlling for post-crash factors will be likely to add to the rigour of the research. Secondly, the data used for this research is administrative data.

Notwithstanding these limitations, the findings of this research provide the necessary evidence to speculate about underlying causality and tailor-made strategies to rectify the risk of severe injury in Victoria.

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