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Differences in risk factors between early and late trauma death after road traffic accidents

Hideo Tohira, Ian Jacobs, David Mountain, Nick Gibson, Allen Yeo

Abstract We aimed to determine the differences in risk factors between early and late trauma death after road traffic accidents. We identified road traffic accident victims from our trauma registry. We defined death that occurred within five days after an accident and death that occurred between 6 and 30 days as early and late trauma death, respectively. We derived two logistic regression models by using early or late trauma death as an outcome measure. We considered a variable significant at the 5% level; significant variables were considered risk factors for early and/or late trauma death. Overall, there were 1,201 victims; 134 and 29 patients experienced early and late trauma death, respectively. The common risk factors for both early and late trauma death included age, Glasgow Coma Scale and systolic blood pressure. We found that the NISS was not a risk factor for late trauma death, although the NISS was a risk factor for early trauma death. Road traffic accident victims aged 65 years or older and/or with a depressed level of consciousness were at increased risk of late trauma death, even if the victims had a low anatomical severity level and survived their first five days after an accident.

Keywords New Injury Severity Score***,*** risk factor, road traffic accident.

I. Background

Identifying risk factors is important in determining a patient's risk of death. For injured patients, risk factors can be classified into three categories: anatomical severity, physiological severity and patient reserve [1]. Anatomical severity describes the degree of anatomical derangement and can be measured by the Injury Severity Score (ISS) or New Injury Severity Score (NISS) [2, 3]. Physiological severity characterises a physiological derangement caused by injury. Systolic blood pressure (SBP), the Glasgow Coma Scale (GCS) and respiratory rate (RR) are included in this category. Patient reserve describes how well a patient can tolerate the impact of anatomical and physiological derangements caused by injury. Although there is no perfect measure for patient reserve, age and comorbidities can be included in this category [1].

Anatomical severity, physiological severity and patient reserve are not the sole determinants of a patient's outcome after injury but interact with each other [1]. For instance, the degree and duration of hypotension caused by a splenic laceration (physiological severity) may be more important than the degree of anatomical damage to the spleen (anatomical severity). Patient reserve determines how well the patient can tolerate this hypotension. With increasing age, a patient may be less tolerable to hypotension due to declined cardiovascular function influenced by morphological changes in the myocardium, conducting pathways, valves and/or vasculature of the heart [4]. Further, wound healing and immune competence also contribute to patient reserve but may decline with advancing age and affect an injured patient's outcome [5].

These risk factors may be important during the early phase of a patient's clinical course but might not be important after the early phase because the cause of death between early and late trauma deaths has been

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reported to be different by a few researchers [6-8]. These researchers have reported that the main causes of early death were exsanguination and severe brain injury and that those of late trauma death were multiple organ failure and sepsis.

A few authors have reported differences in the risk factors for death in relation to time after an event. Perdue et al. reported that the ISS, the Revised Trauma Score (RTS) and geriatric status (age≥65) were common risk factors for early and late death, and they reported that preexisting medical condition was an independent risk factor for late trauma death [9]. Claridge et al. studied risk factors for death during hospitalisation and death after discharge [10]. They reported that the ISS was only a risk factor for death during hospitalisation and that the length of hospital stay and discharge to a locale other than home were only risk factors for death after discharge.

These studies successfully demonstrated the differences in risk factors at various times in the clinical course. However, these studies used a case-mix population not specific to victims of road traffic accidents. Generally, case-mix patients include victims of road traffic accidents, falls and assaults. Overall, victims of road traffic accidents and assaults are younger than those who have suffered falls [11]. In our major trauma patient database acquired from the Royal Perth Hospital (RPH) trauma registry, victims of road traffic accidents and falls account for 75% and 24% of the documented trauma, respectively, and the mean age of victims of road traffic accidents (36 years old) was significantly different from the mean age of fall victims (59 years old) ($p<0.001$). Thus, risk factors identified using a case-mix population might be less accurate than those identified using victims of a specific injury type. Under these circumstances, we raised the following study questions: 1. What are the risk factors for early and late mortality after road traffic accidents? 2. Is there any difference in risk factors between early and late mortality? 3. Who is at risk for late mortality after surviving the early phase of their clinical course? To address these questions, we sought to determine the risk factors for early and late mortality after road traffic accidents.

II. METHODS

Subjects

We used data from the Royal Perth Hospital (RPH) trauma registry acquired between 1994 and 2008. This registry contains only adult patients over the age of 12 who have sustained major trauma. One of the definitions of major trauma is an ISS>15. The detailed definition has been previously defined [12]. We extracted information about victims of road traffic accidents from this registry. A patient was considered a victim of a road traffic accident if they met one of the following criteria: a pedestrian hit by a vehicle, a rider of a bicycle, a driver or pillion passenger of a motorcycle or a driver or passenger of a motor vehicle. Cases with missing data were excluded from this study.

Risk factors

We identified 14 candidate variables as risk factors for trauma death from previous studies [10, 13-16]. These candidate variables included age, SBP, RR, GCS, NISS, major injury to the head, chest, abdomen and/or extremities, preexisting medical conditions, admission to an intensive care unit (ICU), endotracheal intubation at or before arrival to an emergency department (ETI), mechanical ventilation after admission (MV) and type of victim (i.e., pedestrian, a driver of a car, etc.). We used SBP, RR and GCS at admission to the first hospital after an accident. If any of these variables were missing, we used these measures from the scene of the accident, if available, excluding cases if these measures were missing at both times. We used the Abbreviated Injury Scale 2005 update 2008 (AIS 2008) to compute the NISS. The RPH trauma registry included both the AIS 98 and AIS 2005 (2008) codes for injury description. The AIS 2005 and 2008 can be used concurrently and interchangeably because these two AISs were compatible in terms of the injury severity level in most cases [17]. Because injury severity scores based on the AIS 98 were known to be significantly different from those based on the AIS 2005 (2008) [17-20], we converted all AIS 98 codes into AIS 2008 codes using a validated mapping table [21]. We defined a major injury to the head, chest, abdomen and extremity as an injury that had a maximum AIS (MAIS) of 3 or greater. Regarding preexisting medical conditions, we had the Data Linkage Unit (DLU) of the

Department of Health Western Australia link the trauma registry data with the Western Australia hospital morbidity database. Based on the Dartmouth-Manitoba algorithm, which was developed for computing the Charlson Comorbidity Index [22], we identified preexisting medical conditions recorded in the morbidity database within five years before trauma admission. We used the number of preexisting medical conditions instead of the Charlson Comorbidity Index because this number was reported to be a better summary measure for trauma mortality prediction modelling [16]. The victims were divided into 6 categories: a pedestrian hit by a vehicle, a cyclist, a driver or pillion passenger of a motorcycle, a driver of a car, a front passenger of a car or a rear passenger of a car.

We categorised the patients by age, SBP, RR, GCS and NISS. We used the classification used for the Revised Trauma Score to categorise SBP, RR and GCS [23]. We used the classification reported by Copes et al. to categorise the NISS [24]. We collapsed adjacent categories when a null cell count was detected as recommended by Hosmer and Lemeshow [25].

Outcome measure

We identified not only the deaths that occurred during hospital stay but also those that occurred after discharge because the inclusion of only inpatient deaths could underestimate mortality [26]. Skaga et al. reported that 14% of total deaths that occurred within 30 days of the trauma occurred after discharge [26]. We linked the trauma registry data with the Western Australian death registry to identify all deaths that occurred within 30 days after an accident.

We divided all deaths into two categories: deaths that occurred within five days after an accident (early trauma deaths) and deaths that occurred between the 6th and 30th day after an accident (late trauma deaths). We used the 5th day after an accident as a cut-off point because the rate of deaths was no less than 9 deaths per day until the 5th day, where thereafter the rate was no more than 4 deaths per day (Figure 1).

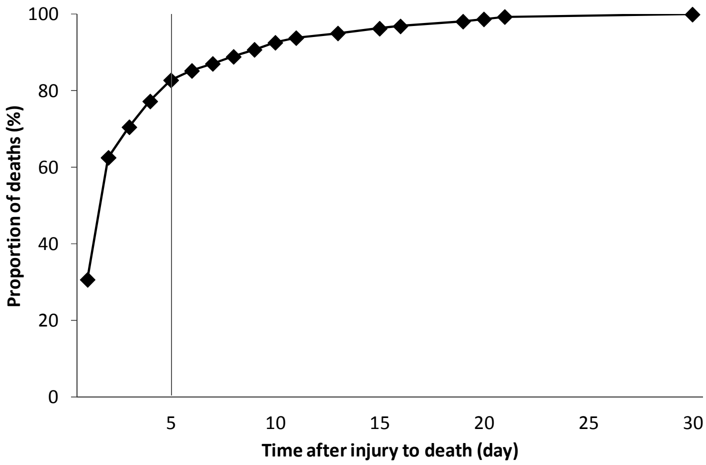

Figure 1. Cumulative frequency curve of deaths based on time after injury.

Statistical analyses

We first derived a logistic regression model by using early trauma death as an outcome measure to identify risk factors for early trauma death. We included all 14 candidate risk factors as independent variables. We selected important variables by using a backward stepwise method [25]. We used the likelihood ratio statistic to decide whether a given variable should be removed from a model. We computed the odds ratios of significant variables by using victims who survived the first seven days after an accident as a reference cohort.

After deriving a model for early trauma death, we excluded early trauma death from the study population because all subjects had to be alive at the 8th day after an accident to derive a model for late trauma death. We subsequently derived a logistic regression model for late trauma death in a similar manner to the model for early trauma deaths. We used victims who survived 30 days after an accident as a reference cohort when computing odds ratios.

Variables were identified as risk factors if their coefficients in the models were found to be significant (as defined by the 5% level).

We used the PASW ver. 18 (IBM, Chicago, Illinois, U.S.) for statistical analyses and data management.

Table 1. Demographics of the study population

	n	(%)
Total	1,201	(100%)
Outcome		
Early trauma death	134	(11.2%)
5-day survivors	1,067	(88.8%)
Late trauma death	29	(2.4%)
30-day survivors	1,038	(86.4%)
Age		
<55	966	(80.4%)
55-64	90	(7.5%)
65-74	65	(5.4%)
>75	80	(6.7%)
Number of PMCs		
0	1,107	(92.2%)
1	68	(5.7%)
>2	26	(2.2%)
GCS		
13-15	751	(62.5%)
9-12	127	(10.6%)
6-8	106	(8.8%)
4,5	64	(5.3%)
3	153	(12.7%)
SBP		
>89	1,037	(86.3%)
76-89	58	(4.8%)
1-75	49	(4.1%)
0	57	(4.7%)
RR		
10-29	908	(75.6%)
>29	149	(12.4%)
1-9	24	(2.0%)
0	50	(4.2%)
Missing	70	(5.8%)
NISS		
<25	402	(33.5%)
25≤, <41	503	(41.9%)
41≤, <50	126	(10.5%)
50≤	170	(14.2%)
Major injuries		
Head	736	(61.3%)
Chest	697	(58.0%)
Abdomen	253	(21.1%)
Extremity	436	(36.3%)
ETI	512	(42.6%)
Mechanical ventilation	557	(46.4%)
Admission to ICU	548	(45.6%)

PMCs: preexisting medical conditions; GCS: Glasgow Coma Scale; SBP: systolic blood pressure; RR: respiratory rate; NISS: New Injury Severity Score; ETI: endotracheal intubation; ICU: intensive care unit

III. RESULTS

There were 1,201 road traffic accident victims during the study period. In total, 134 victims died within five days after trauma, and 1,067 subjects survived their first week after trauma. In the early trauma survivors, we identified 29 late trauma deaths (Table 1). All early trauma deaths and 24 of the 29 late trauma deaths occurred during the hospital stay, and five late trauma deaths occurred after hospital discharge. The majority of the victims were younger than 55 years old (80.4%), had no preexisting medical conditions (92.2%) and exhibited normal physiological parameters (Table 1). Three quarters of victims sustained injuries with a NISS<41 (Table 1). Major head and chest injuries accounted for approximately 60% of all victims, followed by major extremity injuries (36%) and major abdominal injuries (21.1%) (Table 1). Intubation, mechanical ventilation and admission to the ICU were found in approximately 45% of the victims (Table 1). Drivers of motor vehicles were the most frequent type of victim (32.7%), followed by motorcycle drivers (22.6%) and pedestrians (16.4%) (Table 2).

Table 2. Distribution of victims by type

	n	(%)
Pedestrian	197	(16.4)
Cyclist	81	(6.7)
MCA driver	272	(22.6)
MCA pillion passenger	17	(1.4)
MVA driver	393	(32.7)
MVA front passenger	126	(10.5)
MVA back passenger	115	(9.6)
Total	1,201	(100.0)

MCA: motorcycle accident

MVA: motor vehicle accident

Common risk factors for both early and late trauma deaths included age, GCS and SBP at admission (Table 3). Risk factors for late trauma death included only these three factors. The NISS, ETI and admission to the ICU were only risk factors for early trauma death (Table 3). Victims with ETI had the greatest risk of early trauma death (Odds ratio [OR]=169; confidence interval [CI], 42.5 - 676), followed by those who had a NISS≥50 (OR=26.0; 95% CI, 7.61 – 88.6) and those who were 75 years or older

(OR=13.1; 95% CI, 4.76 – 36.1). Admission to the ICU decreased the risk of early death (OR=0.01; 95% CI, 0.002 - 0.03). An age between 65 and 74 years was the greatest risk factor for late trauma death (OR=16.0; 95% CI, 4.76 – 53.7), followed by a GCS=3 (OR=15.7; 95% CI, 4.25 – 57.7) (Table 3). Eight variables (RR at admission, the presence of major head, chest, abdominal or extremity injury, mechanical ventilation after admission, number of preexisting medical conditions and type of victim) were not risk factors for either early or late trauma death. The Wald statistics of major chest and abdominal injuries in the late death model were not significant; however, these two variables remained in the derived model because the fitness of the late death model became significantly worse when these predictors were removed.

Table 3. Summary of the logistic regression models for early and late trauma death

	Early death model				Late death model			
	β	(SE)	Odds ratio (95% CI)	p-value	β	(SE)	Odds ratio (95% CI)	p-value
Age				<0.001				<0.001
<55			1				1	
55-64	0.14	(0.63)	1.15 (0.34 – 4.00)	0.82	0.71	(1.08)	1.07 (0.13 – 8.83)	0.95
65-74	1.16	(0.82)	3.18 (0.63 – 16.0)	0.161	2.77	(0.62)	16.0 (4.76 – 53.7)	<0.001
75-	2.57	(0.52)	13.1 (4.76 – 36.1)	<0.001	2.48	(0.62)	12.0 (3.56 - 40.3)	<0.001
NISS				<0.001				
<25			1					
25≤,<41	0.24	(0.62)	1.27 (0.38 – 4.28)	0.70				
41≤,<50	1.05	(0.71)	2.85 (0.716 – 11.5)	0.14				
50≤	3.26	(0.63)	26.0 (7.61 – 88.6)	<0.001				
GCS				<0.001				<0.001
13-15			1				1	
9-12	0.62	(0.58)	1.86 (0.63 – 5.55)	0.26	1.54	(0.62)	4.65 (1.37 – 15.8)	0.014
6-8	-1.32	(0.83)	0.27 (0.05 - 1.37)	0.11	2.05	(0.70)	7.80 (1.99 - 30.5)	0.003
4-5	0.97	(0.62)	2.65 (0.79 – 8.92)	0.12	2.61	(0.67)	13.6 (3.70 – 50.4)	<0.001
3	2.08	(0.52)	7.99 (2.90 – 22.1)	<0.001	2.75	(0.67)	15.7 (4.25 – 57.7)	<0.001
SBP				0.002				0.01
≥90			1				1	
76-89	-0.17	(0.66)	0.84 (0.23 – 3.04)	0.79	0.26	(1.07)	1.03 (0.13 – 8.34)	0.98
1-75	0.39	(0.61)	1.48 (0.45 – 4.89)	0.52	2.08	(0.62)	8.01 (2.39 – 26.8)	0.001
0	2.21	(0.59)	9.11 (2.86 - 29.0)	<0.001	1.06	(1.15)	2.89 (0.31 – 27.4)	0.36
Intubation	5.13	(0.71)	169 (42.5 - 676)	<0.001				
ICU admission	-4.76	(0.64)	0.01 (0.002 - 0.03)	<0.001				
Chest injury					0.75	(0.45)	2.12 (0.88 – 5.09)	0.93
Abdominal injury					-2.08	(1.06)	0.13 (0.02 - 1.00)	0.0501
Constant	-5.53	(0.61)		<0.001	-5.84	(0.59)		0.003

SE: standard error; CI: confidence interval; NISS: New Injury Severity Score; GCS: Glasgow Coma Scale; PMC: preexisting medical condition; SBP: systolic blood pressure; ICU: intensive care unit

IV. DISCUSSION

We investigated risk factors for early and late trauma death after a traffic accident using logistic regression analyses. Common risk factors for early and late trauma death included age, the GCS and the SBP at admission. ETI before or at admission showed the greatest risk for early trauma death, and geriatric status (age≥65 years old) posed the greatest risk for late trauma death. The NISS was a risk factor for early trauma death but not late trauma death.

In injury research, various outcome prediction models have been developed to estimate outcome, identify preventable deaths and evaluate hospital trauma care performance. These conventional models include variables that may be unimportant and do not consider time of death. For instance, the Trauma and Injury Severity Score (TRISS) and A Severity Characterisation of Trauma, which are well-known outcome prediction models, both consider early and late mortality as the same outcome [27, 28]. They also include RR and anatomical severity for predictors [27, 28]. In our study, we found that anatomical severity was a risk factor only for early trauma death and that RR was not a risk factor for either early or late mortality. These findings suggest that using separate models for early and late trauma death might predict the outcome more accurately than a single model that considers both early and late trauma death.

We found that an age of 65 years or older and low GCS at admission were two major risk factors for late mortality. We also found that the anatomical severity was independent of late trauma death even though anatomical severity has generally been included in conventional outcome prediction models as a risk factor (e.g., TRISS). These findings might suggest that clinicians should pay more attention to elderly victims whose GCS is subnormal to prevent unnecessary deaths, even if these victims sustained low severity injury and survived their first five days.

The type of victim was not a risk factor for either early or late mortality. A few studies reported that pedestrians were at the highest risk of death among all road-user groups regardless of similar injury severity level [29-31]. In contrast, we demonstrated that the type of victim was an insignificant factor after adjusting for age and other covariates. The insignificance of type of victim may be explained by a higher proportion of older population among pedestrians than other road user groups. Older people (age≥65) accounted for 26%, 1% and 12% of pedestrians, motorcycle riders and motor vehicle occupants, respectively. This high proportion of elderly victims in pedestrians is supported by other reported studies [29, 32, 33].

Our findings were different from a previous study in some aspects [9]. Perdue et al. reported that the Injury Severity Score (ISS), which is a measure of anatomical injury severity, was a common risk factor for early and late trauma death. They also showed that preexisting medical conditions were a risk factor for late mortality, whereas we found that preexisting medical conditions were not a risk factor for early and late mortality. These differences might be explained by the difference in the methodology between their study and ours. They defined a death that occurred within 24 hours after an event and a death that occurred later than 24 hours after an event as early and late trauma death, respectively; we used the 5th day after injury as a cut-off point to separate early and late trauma death. Furthermore, they used a case-mix population, whereas we only used victims of road traffic accidents. A standardised definition for early and late trauma death may facilitate risk factor analyses of injured patients in relation to time after an event.

We found that both ETI and admission to the ICU were risk factors for early trauma death. These two risk factors are medical interventions utilised in patients with a risk of death. However, we found contrasting results for these risk factors. ETI was the greatest risk factor for early trauma death, while admission to the ICU decreased the risk for early death. In our subjects, intubated patients showed a greater NISS, decreased blood pressure, decreased respiratory rate and a lower GCS than those admitted to the ICU. Furthermore, most deaths of intubated patients occurred in the emergency department before ICU admission. Considering these observations and clinical plausibility, the high OR of ETI does not indicate that ETI was harmful to trauma patients but might indicate that ETI was performed for patients with the greatest risk among all victims before ICU admission.

A depressed GCS score was a risk factor for late trauma death, whereas major head injury defined as a head AIS≥3 was not a risk factor. This discrepancy can be explained by the difference in the classification of the severity of traumatic brain injury (TBI). We used a score based on the AIS in order to keep consistency with classifications of major injury in other body regions (i.e., major chest injury). However, studies of TBI usually use the GCS to classify the severity of TBI [34]. For instance, Stein et al. defined a GCS of 14-15, 9-13, 5-8 and 3-4 as minimal or mild, moderate, severe and critical, respectively [35]. According to this classification, our results suggest that moderate and severe brain injuries were risk factors for late trauma death. The discrepancy between AIS-based and GCS-based classifications might be also explained by the fact that there was no correlation between head AIS and total GCS score on the basis of outcomes of patients with brain injuries [36].

The discrepancy between AIS-based and GCS-based classifications also suggests that the GCS might be a better measure to assess the severity of brain injury than head AIS. The AIS provides a detailed classification of injuries with a severity level, and this severity level has been used in injury biomechanics research to quantify the level of the anatomical damage that was caused by external force. However, as described above, major head injury that was based on head AIS was not a risk factor for either early or late trauma death, while a depressed GCS score was a significant risk factor for both early and late trauma death. Timmons et al. recently reported similar results to ours [37]. They studied the performance of the GCS and head AIS to predict 2-week mortality. This study demonstrated that a total GCS score and GCS motor score were more strongly associated with 2-week mortality than head AIS. It is true that there are limitations for the use of the GCS. For instance, a GCS score is inaccurate if a patient was intoxicated or paralyzed and inappropriate if a patient was intubated before a GCS score was calculated. However, if possible and available, injury biomechanics researchers might need to consider the use of the GCS to measure the severity of head injury because a GCS score is a stronger predictor of mortality of patients with TBI than head AIS.

The limitation of this study was the small sample size, as indicated by the broad 95% CIs of ORs. We also needed to collapse adjacent categories of predictor variables because null cell counts were detected. We categorised all deaths into two categories based on the time of death, although other researchers classified deaths into three or more categories (e.g., acute, early and late trauma death) by using larger databases [6-8, 38, 39]. The use of a larger database for road traffic accidents will overcome this limitation.

V. CONCLUSION

We found differences in risk factors between early and late death after road traffic accidents. The NISS was not a risk factor for late trauma death although the NISS was one of several risk factors for early trauma death. Health professionals should consider that victims of road traffic accidents who are 65 years of age or older and/or demonstrate a depressed level of consciousness at admission are at increased risk of late trauma death, even if the victims had a lower anatomical severity level and survived their first five days after an accident.

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