Computational analysis of factors affecting the probability of survival in trauma injuries

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Computational Analysis of Factors Affecting the Probability of Survival in Trauma Injuries

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Abstract—A preliminary computational analysis of a number of factors affecting the probability of survival in trauma injuries was carried out. The study examined the manner the types and extent of body injuries, specific body regions affected by the injuries, pre-exiting medical conditions, physiological parameters (e.g. heart rate, blood pressure and respiration rate), age, gender and Glasgow Comma Score contribute to the probability of survival. A more in depth analysis of these factors are currently ongoing to develop a model for the probability of survival.

Keywords—computational analysis of injuries, probability of survival

I. INTRODUCTION

Trauma injury is an important cause of death and disability [1]. Determining the probability or likelihood of survival in trauma injuries is important for triage, setting treatment priorities and research and management audit [2]. Numerous parameters influence the probability of survival that include extent, type and location of body injuries, pre-existing medical conditions (such as a heart illness), physiological parameters (such as heart rate, blood pressure and respiration rate), age, gender, frailty and neurological parameters that indicate the level of conscious state. A complicating factor is the manner and extent of interaction and interrelations of these parameters on the probability of survival.

In order to obtain the anatomical and neurological injury related information, a number of standard scoring systems are available. A commonly used system for assessing anatomical injuries is the Abbreviated Injury Scale (AIS) [3]. It was introduced in 1971 by the Association of the Advancement of Automotive Medicine to aid vehicle crash investigators. It has been since been revised to be more relevant to medical audit and research. AIS classifies injuries in all body regions according to their relative importance. It uses the 6 points ordinal severity scale defined as 1=minor, 2=moderate, 3=serious, 4=severe, 5=critical, 6=maximum (currently untreatable). It defines body region injuries in a dictionary that has nine separate chapters defined as; (i) Head, (ii) Face, (iii) Neck, (iv) Thorax, (v) Abdomen and pelvic contents, (vi) Spine, (vii) Upper extremities, (viii) Lower extremities and (ix) External (skin), burns and other trauma. In order to determine an overall trauma injury score for patients with multiple trauma injuries, the Injury Severity Score (ISS) could be used. This an anatomical scoring system with the maximum total score of 75 that selects the highest AIS values in each body region [4]. The three most severely injured regions (corresponding to 3 largest scores) have their scores squared and then summed to produce the ISS value.

A well-known injury scoring system to determine the level of consciousness (neurological) is the Glasgow Coma Scale (GCS) [5]. It allocates scores to eye opening, verbal response and motor response as indicated in Table I.

TABLE I. OVERVIEW OF INJURY CASES

Eye Opening	Verbal Response	Motor Response
4=spontaneous	5=normal conversation	6=normal
3= to voice	4=disoriented conversation	5=localised to pain
2=to pain	3=words, but not coherent	4=withdraws to pain
1= none	2=no words only sounds	3=decorticate posture
	1=none.	2=decerebrate
		1=none

The primary aim of this study is develop techniques that will result in improving the accuracy of determining the probability of survival. A number of approaches currently exist that may be used to determine the probability of survival, but as outlined in the next section these have some limitations. In the next sections a brief overview of some existing methods for determining the probability of survival is provided, study's methodology and its results are explained.

II. APPROCHES TO DETERMINE PROBABILITY OF SURVIVAL

Trauma and Injury Severity Score (TRISS) uses anatomical and physiological scoring systems to determine the probability of survival (p_s) for adults sustaining traumatic injuries from blunt and penetrating mechanisms [6], where p_s is calculated as.

$$p_s = \frac{1}{1+e^{-b}} \tag{1}$$

$$b = \alpha_i + \beta_{AGE,i} \times \beta_{RTS,i} \times RTS + \beta_{ISS,i} \times ISS$$

i = 1 is for blunt mechanism and i=2 is for penetrating mechanism, α_{i} is a constant for mechanism i, $\beta_{\mathrm{AGE,i}}$ is the coefficient associated with AGE and mechanism i, $\beta_{\mathrm{RTS,i}}$ is the coefficient associated with RTS and mechanism i, and $\beta_{\mathrm{ISS,i}}$ is the coefficient associated with ISS and mechanism i. RTS is obtained by

$$\mathrm{RTS} = \beta_{\mathrm{RR}} \times \mathrm{RR} + \beta_{\mathrm{SBP}} \times \mathrm{SBP} + \beta_{\mathrm{GCS}} \times \mathrm{GCS} \qquad (2)$$

where β_{RR} is the coefficient associated with respiration rate (RR), β_{SBP} is the coefficient associated with systolic blood pressure (SBP), and β_{GCS} is the coefficient associated with GCS. TRISS however has a number of shortcomings as explained in [7].

In 2004, Trauma Audit and Research Network (TARN) [8] proposed a Probability of Survival model called PS12. This model uses age, gender, Injury Severity Score (ISS) and GCS and intubation. In 2014, PS14 model was introduced by incorporating Charlson Comorbidity Index (CCI) [9] to the assess Pre-Existing Medical Conditions (PMC).

To predict probability of survival in PS14, age, gender, GCS and intubation and PMC parameters are required. It determines the percentage of probability of survival by performing retrospective measure of a new patient with same profile on TARN database (that has information on very large number of trauma injury cases and their associated outcome as survived or not survived). For example, if ps = 53%, then 53 out of every 100 people have profiles that survived and 47 people died based on formula.

$$\mathrm{p_s} = \frac{\mathrm{e^b}}{1 + \mathrm{e^{-b}}} \qquad (3)$$

where e=2.718282 and b is defined as the linear combination of the regression coefficients and the values of the corresponding patient's characteristics (ISS, GCS, modified CCI, age and gender).

III. METHODOLOGY

This study is in collaboration with Trauma Audit and Research Network (TARN). The data provided by TARN for the purpose of this study contained 47,702 trauma injuries cases that indicated subject details and their associated trauma injury information (age, gender, AIS and GCS values, blood pressure, heart rate, respiration rate etc.) and outcome of trauma injury as survived (lived) or not survived (died). The study is currently using this data to create a knowledge base that maps the trauma injury related information to survival outcome. The development of the knowledge based required a computation analysis of the trauma injury data and this analysis is the focus of this paper. The mechanism that uses the analysis results and determines the probability of survival is currently in the process of being developed and thus is not described in this paper.

The computation analysis was performed using SPSS© and Matlab© packages. The analysis examines the manner individual and a combination of trauma injury factors influenced survival outcome.

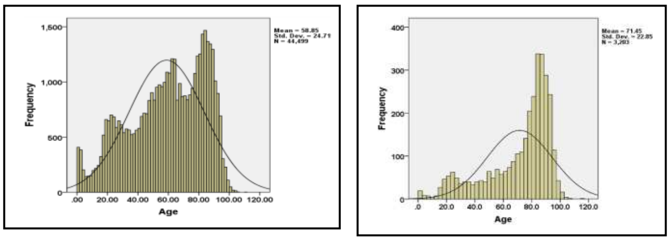
IV. RESULTS AND DISCUSSION

Table II indicates the number of cases used in the study, their gender, age, injury types and injury outcomes. There are more male cases and 97% of the injuries were in the blunt category and the rest penetrating type. A blunt traumatic injury is caused by the application of mechanical force to the body or when the body strikes a surface in which the skin is not penetrated. A penetrating traumatic injury is caused when an object such as knife penetrates the body. Of included cases, 93.3% survived (lived) and the remaining not survived (died) from their trauma injuries.

TABLE II. OVERVIEW OF INJURY TTAUMA CASES

Gender (%)		**Mean Age (years)** (standard deviation)	**%Injury Type**		**Injury Outcome (%)**	
Male	Female		Blunt	Penetrating	Lived	Died
26098 (54.7)	21604 (45.3)	60.7 (24.8)	97	2.4	44499 (93.3)	3203 (6.7)

Figs.1a and b show the distributions (histogram of frequency against age) of the effect of age on individuals surviving (lived) and not surviving (died) a traumatic injury. The distribution for survived cases shows peaks at 20, 60 and 80 years but for those that did not survive, there is a single dominant peak at about 90 years.



(a) (b)

Fig.1 (a) Age distribuition of indiviuals suviving and (b) those not surviving.

Fig.2 shows the number of cases for different injury mechanisms. The dominant injuries are: fall less than 2 m, vehicle incident collisions, fall more than 2 m and blow(s). Fig.3 shows the injury numbers in relation to AIS defined body regions. Lower limbs injuries followed by head, thorax, spine and upper limbs are the main affected regions.

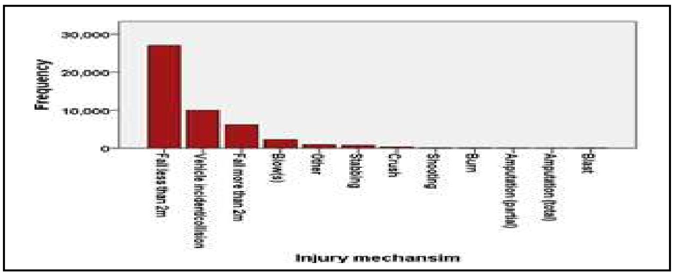


Fig.2 Number of cases for different injury mechanisms.

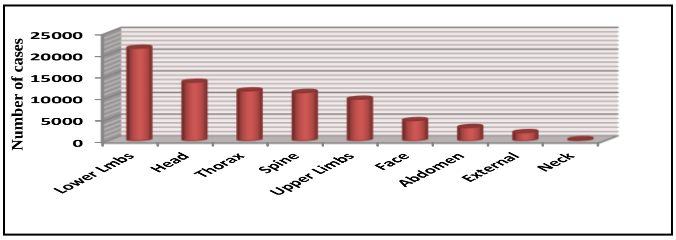


Fig.3 Injury numbers in relation to the AIS defined body regions.

Fig.4 provides the percentages of cases with AIS injury scores 3-6 that did not survive. The majority of these cases had head injury (43.93%) and next highest percentages were for thorax (22.04%) and lower limbs (15.55%).

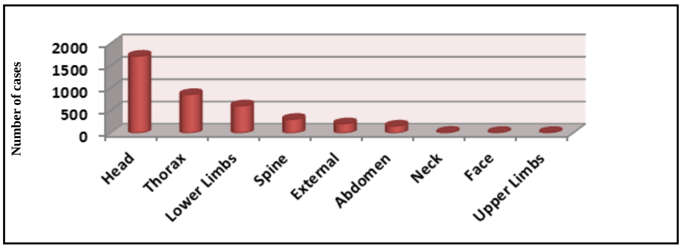
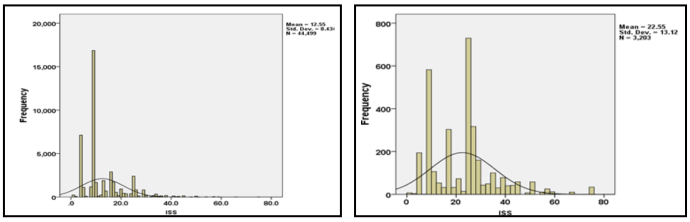


Fig.4 Body region injuries with AIS scores 3-6 and associated number of cases not survived.

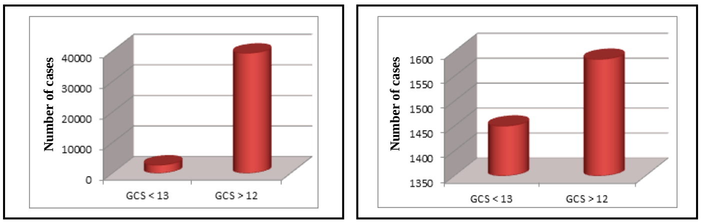
Figs.5a and b show the distributions the ISS scores for (a) those that survived and (b) those that did not. For those that survived the ISS values peak around 15 and for those that did not, the ISS distribution has multiple peaks, with the largest at round 30.



(a) (b)

Fig.5 (a) Distribuition of ISS values for (a) those that survived and (b) those that did not survive.

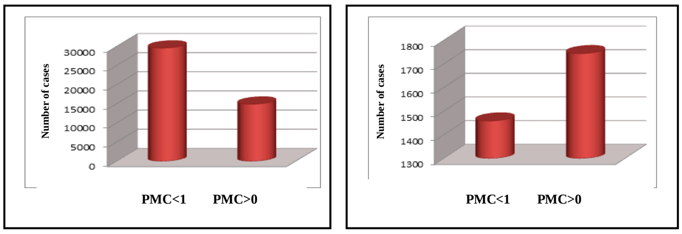
Figs.6 shows the number of cases with GCS less than 13 and more than 12 that survived. Fig.6b shows similar information for those that did not survive. Comparing the proportion of cases with GCS less than 13 against those with more than 12, for those who did not survive this proportion is much higher.



(a) (b)

Fig.6 (a) GCS values (a) those that survived and (b) those that did not survive.

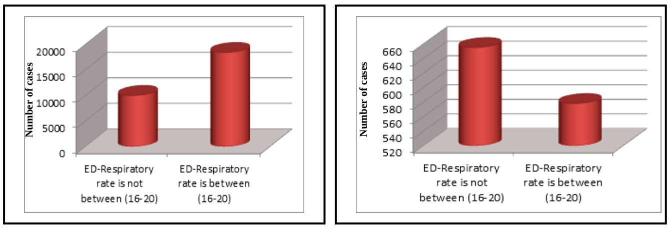
Figs.7a and b show the effects of pre-existing medical conditions (PMC) on the probability of survival for cases that (a) survived and (b) did not survive. PMC<1 indicates no pre-existing condition and PMC>0 indicates existence of at least a pre-existing medical condition. The majority of those that survived did not have a pre-existing medical condition but the opposite is the case for those that did not.



(a) (b)

Fig.7 (a) The effect of pre-existing medical condition on (a) those that survived and (b) those that did not survive.

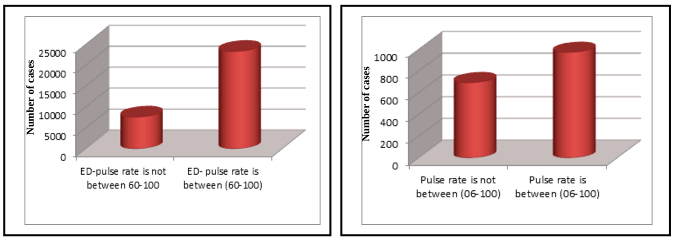
Figs. 8a and b show the number of adult cases with emergency department respiratory rate in the normal range (16 to 20 cycles per minute) for cases (a) that survived and (b) those that did not. The proportion of cases with emergency department respiratory rate 16-20 cycles per minute that did survived is much higher than the cases that did not. Therefore the respiratory rate is an important factor in determining the probability of survival.



(a) (b)

Fig.8 (a) Number of cases with normal (15 to 20 cycles per minute) emergency department respiratory rate (a) those that survived and (b) those that did not survive.

Figs.9a and b show the effect of normal pulse (heart) on survival in adult cases. Pulse rate for healthy adults is between 60-100 bpm. In survived cases (Fig.9a), a much larger number of individuals had normal pulse rate. Fig.9b shows the proportion of the individuals with a normal and abnormal emergency department pule rate for cases that did not survive is much closer than those that did survive.



(a) (b)

Fig.9 Effect of emergency department pulse (heart) rate on probabbility of survival in adults (a) survived cases (b) those that did not survive.

Fig.10 shows the AIS score of the cases with joint head, thorax and lower limb injuries (i.e. the main body areas affected by trauma injury) that did not survive. The largest number of deaths is for head (score 5), thorax (score 3) and lower limbs (scores 4 and 5) injuries.

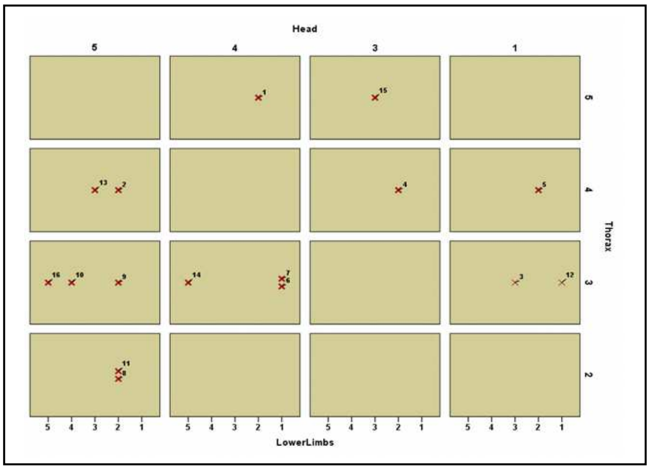
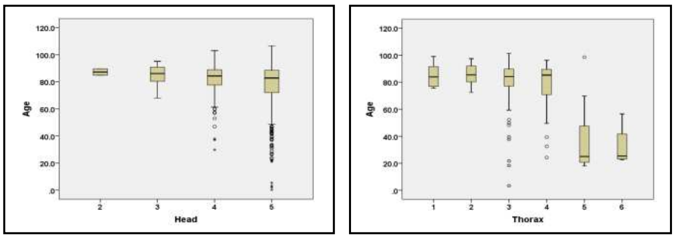


Fig.10 The interrelationship between trauma injuries associated with head, thorax, and lower limb in cases that did not survive represented by AIS values 1-5.

Figs.10a and b show box plots that indicate the relation between head injury only and thorax injury only for cases that did not survive. Both injury types have mainly AIS value 5 but age ranges are different.



(a) (b)

Fig.10 Box plots indicating the relationship between (a) head only injury and (b) thorax only injury for those that did not survive.

Fig. 11 shows the correlation between injuries associated with the 8 body regions as defined in AIS for cases that did not survive. Head injury occurs more often with face and thorax injuries. Face injury occurs more often with head injury. Thorax injury occurs more often with head and abdomen injuries.

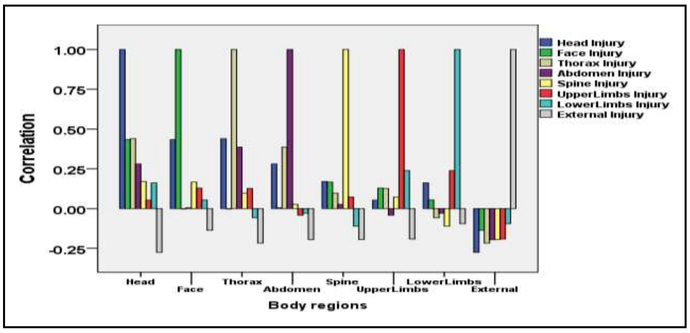


Fig.11 Correlation analysis of trauma injuries associated with the AIS defined body regions in cases that did not survive.

Fig.12 shows the interrelationship between age, GCS and head only injury in cases that did not survive. Most cases are related head injury AIS 5, ages around 80 years. Most head injuries with AIS score 4 have GCS values 3-5 and 11-15.

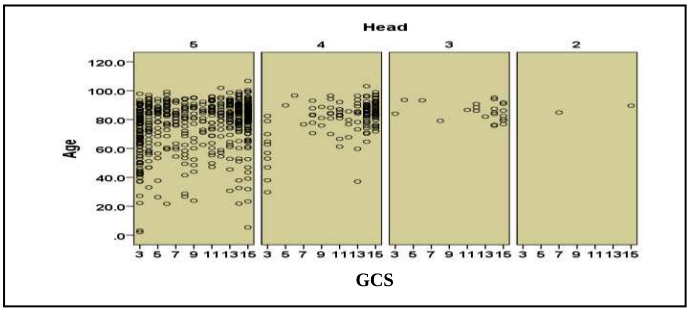


Fig.12 The interrelationship between GCS and head injury in cases that did not survive.

Fig.13 shows analysis in Fig.12 extended with gender included. Gender is a more significant factor in determining the probability of survival in older subjects. A larger number of older (aged around 80 years) males have head injury than females. Age can be important in determining the probability of survival [10].

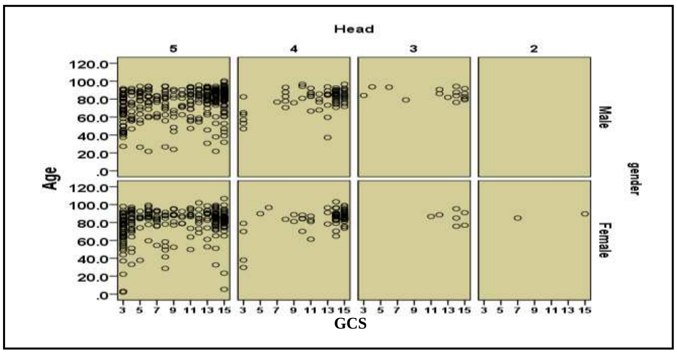


Fig.13 The interrelationship between GCS, head injury and age in cases that did not survive.

Fig.14 shows the relationships between injury mechanisms, GCS, pre-existing medical condition (PMC) and head only injury in cases that did not survive. Most cases that did not survive are associated with fall less than 2 m, AIS values 4 and 5 and lower (-1 to 15) values of PMC. GCS values 3-7 and 13-15 included more cases that did not survive.

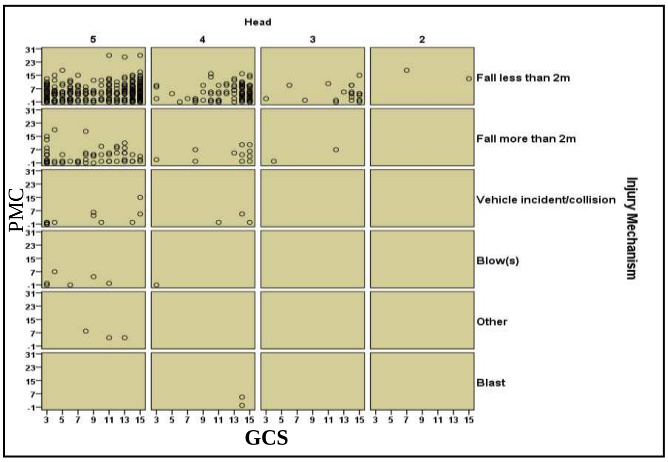


Fig.14 Relationship for GCS, PMC, injury mechanisms and head only injury for cases that did not survive.

Table III provides a summary the interrelationships between injuries associated with specific body regions and factors affecting the probability of survival (age, PMC, GCS and gender) in cases that did not survive. Both the number of cases and respective percentages are included.

TABLE III. OVERVIEW OF INJURY CASES

Body regions	**Total**	**Age (%)**		**PMC (%)**		**GCS (%)**		**Gender (%)**	
		>57	**<55**	**<=0**	**>0**	**<13**	**>=13**	**Male**	**Female**
Head	811	745 (91.9)	66 (8.1)	289 (35.6)	522 (64.4)	402 (49.6)	409 (50.4)	362 (44.6)	449 (55.4)
Lower Limbs	347	335 (96.5)	12 (3.5)	105 (30.3)	242 (69.7)	9 (2.6)	338 (97.4)	119 (34.3)	228 (65.7)
Thorax	194	166 (85.6%)	28 (14.4)	76 (39.2)	118 (60.8)	35 (18.0)	159 (82.0)	110 (56.7)	84 (43.3)
Head & Face	129	103 (79.8)	26 (20.2)	49 (38.0%)	70 (54.3)	64 (49.6)	62 (48.1)	79 (61.2)	50 (38.8)
Head& Thorax and Lower limbs	16	11 (68.8)	5 (31.3)	10 (62.5)	6 (37.5)	12 (75.0)	4 (25.0)	7 (43.8)	9 (56.3)

V. CONCLUSIONS

A preliminary computational analysis of a number of important factors that influence the probability of survival in traumatic injuries was performed. The study highlighted some of the complexities associated with the manner traumatic injuries affect the probability of survival. We are currently building on this analysis to develop a model that can indicate the probability of survival and overcome some limitations of the existing models. The main element of this model is its knowledge base that will be derived from the TARN trauma injury data base. The processing of the information in the knowledge base will be based on the artificial intelligence method of fuzzy logic. The fuzzy logic compares injury information about a case with those in the data base to determine the likelihood of the survival.

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