Original Article

Prediction of Outcome Based on Trauma and Injury Severity Score, IMPACT and CRASH Prognostic Models in Moderate-to-Severe Traumatic Brain Injury in the Elderly

Abstract

Objectives: This study aimed to evaluate the trauma and injury severity score (TRISS), IMPACT (international mission for prognosis and analysis of clinical trials), and CRASH (corticosteroid randomization after significant head injury) prognostic models for prediction of outcome after moderate-to-severe traumatic brain injury (TBI) in the elderly following road traffic accident. **Design:** This was a prospective observational study. **Materials and Methods:** This was a prospective observational study on 104 elderly trauma patients who were admitted to tertiary care hospital, over a consecutive period of 18 months from December 2016 to May 2018. On the day of admission, data were collected from each patient to compute the TRISS, IMPACT, and CRASH and outcome evaluation was prospectively done at discharge, 14th day, and 6-month follow-up. **Results:** This study included 104 TBI patients with a mean age of 66.75 years and with a mortality rate of 32% and 45%, respectively, at discharge and at the end of 6 months. The predictive accuracies of the TRISS, CRASH (computed tomography), and IMPACT (core, extended, laboratory) were calculated using receiver operator characteristic (ROC) curves for the prediction of mortality. Best cutoff point for predicting mortality in elderly TBI patients using TRISS system was a score of ≤88 (sensitivity 94%, specificity of 80%, and area under ROC curve 0.95), similarly cutoff point under the CRASH at 14 days was score of >35 (100%, 80%, 0.958); for CRASH at 6 months, best cutoff point was at >84 (88%, 88%, 0.959); for IMPACT (core), it was >38 (88%, 93%, 0.976); for IMPACT (extended), it was >27 (91%, 89%, 0.968); and for IMPACT (lab), it was >41 (82%, 100%, 0.954). There were statistical differences among TRISS, CRASH (at 14 days and 6 months), and IMPACT (core, extended, lab) in terms of area under the ROC curve ($P < 0.0001$). **Conclusion:** IMPACT (core, extended) models were the strongest predictors of mortality in moderate-to-severe TBI when compared with the TRISS, CRASH, and IMPACT (lab) models.

Keywords: *Corticoid randomization after significant head injury, elderly, international mission on prognosis and analysis of clinical trials, mortality, trauma and injury severity score, trauma, traumatic brain injury*

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Introduction

Traumatic brain injury (TBI) remains the leading cause of death and disability worldwide as well as the most important single injury contributing to traumatic mortality and morbidity.[1]

Older age has been recognized as an independent predictor of worse outcome from TBI. Two major factors place older adults at risk for the greater incidence of TBI. First, as one ages, the duramater becomes more adherent to the skull. Second, as part of routine management of chronic conditions, older adults receive aspirin and anticoagulant therapies. Thus, the mechanisms of injury most likely to be seen in elderly persons increase the risk for TBI. Other normal aging changes include cerebrovascular atherosclerosis and decreased free radical clearance.[2]

Establishing an early and reliable prognosis in patients with TBI has proved particularly challenging.[3,4] Prognostic models, which generally characterize prognostic research, are statistical models that use two or more variables to calculate the probability of a predefined outcome.[5]

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The international mission for prognosis and analysis of clinical trials

The international mission for prognosis and analysis of clinical trials (IMPACT) study is the result of pooled data from eight randomized controlled trials, three observational studies were conducted between 1984 and 1997.[6,7]

IMPACT has three levels of complexity, from the simplest core model to the extended and the most complex laboratory model. The core model consists of age, the motor score component of the Glasgow Coma Scale (GCS), and pupillary light reactivity. The addition of hypoxia, hypotension, and head computed tomography (CT) scan characteristics makes up the extended model. For the laboratory model, blood hemoglobin and glucose concentrations are also added [Table 1].[8]

Six LPs were defined as follows:

LPcore, mortality =−2.55 + 0.275* sum score core

LPcore, unfavorable =−1.62 + 0.299* sum score core

LPextended, mortality =−2.98 + 0.256* sum score extended

LPextended, unfavorable =−2.10 + 0.276* sum score extended

LPlab, mortality =−3.42 + 0.216* sum score lab

LPlab, unfavorable=−2.82 + 0.257* sum score core lab

Table reproduced from Steyerberg *et al*., PLoS Medicine 5(8):5165.

The corticosteroid randomization after significant head injury

The corticosteroid randomization after significant head injury (CRASH) prognostic model is the result of the MRCCRASH meta-trial investigating the role of corticosteroids in patients with TBI.[9] Like IMPACT, CRASH is based on admission characteristics to predict probabilities of 14-day mortality and 6-month neurological outcome on the GCS. CRASH has two levels of complexity, a basic model and an extended version with CT scan characteristics. The basic model includes age, GCS, pupillary light reaction, and presence of major extracranial injury. CT scan characteristics added for the extended model are the presence of petechial hemorrhage, status of the third ventricle and basal cisterns, presence of traumatic subarachnoid hemorrhage, midline shift, and mass lesion. Moreover, CRASH is calibrated differently for patients from low- and middle-income countries and high-income countries.[9-12]

Trauma and injury severity scores

Trauma and injury severity score (TRISS) determines the probability of survival (Ps) of a patient from the injury severity score (ISS) and revised trauma score (RTS) using the following formulae:

Ps = 1/(1+ e–b)

Table 1: The International Mission for Prognosis and Analysis of Clinical Trials in traumatic brain injury model

Characteristics	Value	Score	Sum
Age (Years)	<30	0	
	30-39	1	
	40-49	2	
	50-59	3	
	60-69	4	
	>70	5	
Motor Score	None/Extension	6	
	Abnormal Flexion	4	
	Normal Flexion	2	
	Localizes/Obeys	0	
	Untestable/Missing	3	
Pupillary Reactivity	Both Pupils reacted	0	
	One Pupil reacted	2	
	No Pupil reacted	4	
	Sum score core model		
Hypoxia	Yes/Suspected	1	
	No	0	
Hypotension	Yes/Suspected	2	
Ct Classification	No	0	
Traumatic SAH	I	-2	
Epidural Hematoma	II	0	
	III/IV	2	
	V/VI	2	
	Yes	2	
	No	0	
	Yes	-2	
	No	0	
	Sub score CT		
	Sum Score Extended Model		
Glucose (Mmol/dl)	<6	0	
	6-8.9	1	
	9-11.9	2	
	12-14.9	3	
	>15	4	
HB (gm/dl)	<9	3	
	9-11.9	2	
	12-14.9	1	
	>15	0	
	Sub score lab		
	Sum score lab model		

Sum scores can be calculated for the core model (age, motor score, pupillary reactivity), the extended model (core + hypoxia + hypotension + CT characteristics), and a lab model (core + hypoxia + hypotension + CT + glucose + Hb). The probability of 6-month outcome is defined as 1 / (1 + e-LP), where LP refers to the linear predictor in a logistic regression model. CT – Computed tomography; Hb – Hemoglobin; LP – linear predictor in a logistic regression model.

Where "b" is calculated from:

$$b = b0 + b1 (RTS) + b2 (ISS) + b3 (Age\ Index)$$

The coefficients b0–b3 are derived from multiple regression analysis of the major trauma outcome study database. [Table 2]. Age Index is 0 if the patient is below 54 years of age or 1 if 55 years and over. b0–b3 are coefficients which are different for blunt and penetrating trauma. If the patient is less aged than 15 years, the blunt coefficients are used regardless of mechanism. The TRISS calculator determines the probability of survival from the ISS, RTS, and patient's age. ISS and RTS scores can be given independently or calculated from their base parameters.[13]

TRISS uses a combination of both anatomic and physiologic scoring systems and gives a more accurate probability of survival.
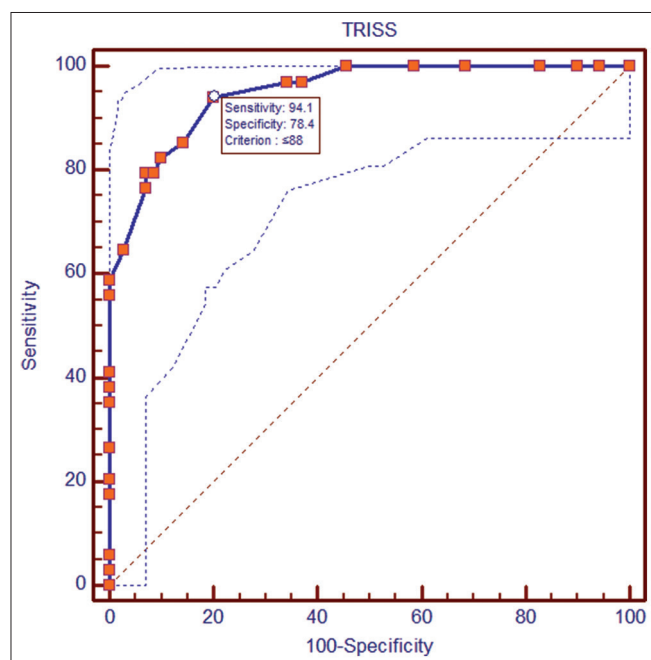
Materials and Methods

Inclusion criteria

(1) Age equal to or older than 60 years
(2) GCS score ≤12 on admission.

Table 2: TRISS coefficient

	Blunt	Penetrating
b0	−0.4499	−2.5355
b1	0.8085	0.9934
b2	−0.0835	−0.0651
b3	−1.7430	−1.1360

Graph 1: Receiver operator characteristic curve showing validity of trauma and injury severity score in predicting mortality at discharge

Table 3: Demographic profile of subjects in the study (*n*=104)

	Count (%)
Age (years)	
60-70	80 (76.9)
71-80	21 (20.2)
>80	3 (2.9)
Sex	
Female	29 (27.9)
Male	75 (72.1)
Intubation	
I	50 (48.1)
N	54 (51.9)
Outcome at discharge	
Discharged	70 (67.3)
Mortality	34 (32.7)
6-month mortality	
Favorable	59 (56.7)
Unfavorable	45 (43.3)

Table 4: Factors associated with mortality at discharge

	Total (*n*=104)	At discharge, count (%)		*P*
		Discharged	Mortality	
Age (years)				
60-70	80	60 (75)	20 (25)	0.002*
71-80	21	10 (47.6)	11 (51.3)	
>80	3	0 (0)	3 (100)	
GCS				
3	8	0 (0)	8 (100)	<0.001*
4	5	0 (0)	5 (100)	
5	4	0 (0)	4 (100)	
6	3	1 (33.3)	2 (66.6)	
7	8	6 (75)	2 (25)	
8	5	1 (20)	4 (80)	
9	9	4 (54.5)	5 (44.4)	
11	10	9 (90)	1 (10)	
12	52	49 (94.2)	3 (5.7)	
ISS				
1-24	91	70 (76.9)	21 (22.1)	<0.001*
25-75	13	0 (0)	13 (100)	
Pupils				
ER	78	66 (84.6)	12 (15.3)	<0.001*
NR	7	0 (0)	7 (100)	
UR	19	4 (21)	15 (79)	
EDH				
No	81	58 (71.6)	23 (28.4)	0.080
Yes	23	12 (52.1)	11 (47.8)	
SDH				
No	59	45 (76.2)	14 (23.7)	0.026*
Yes	45	25 (55.5)	20 (44.5)	
SAH				
No	45	34 (75.5)	11 (24.5)	0.117
Yes	59	36 (61)	23 (39)	

ISS-Injury severity score; GCS-Glasgow Coma Scale; ER-Equally reactive; NR-Non reactive; UR-Unequally reactive; EDH-Epidural Hemorrhage; SDH-Sub Dural Hemorrhage; SAH-Sub Arachnoid Hemorrhage; *-0.05

Exclusion criteria

(1) Patients discharged against medical advice
(2) Patients/attendants of patients who were not willing to participate in the study [Figure 1].

Table 5: Factors associated with mortality at 6 months

|	Total (*n*=104)	6-month mortality, count (%)		*P*
		Favourable	Unfavourable	
Age (years)				
60-70	80	49 (61.2)	31 (38.7)	0.07
71-80	21	10 (47.6)	11 (52.4)	
>80	3	0 (0.0)	3 (100)	
GCS				
3	8	0 (0.0)	8 (100)	<0.001*
4	5	0 (0.0)	5 (100)	
5	4	0 (0.0)	4 (100)	
6	3	0 (0.0)	3 (100)	
7	8	0 (0.0)	8 (100)	
8	5	1 (20)	4 (80)	
9	9	2 (22.2)	7 (77.7)	
11	10	9 (90)	1 (10)	
12	52	47 (90.3)	5 (9.6)	
ISS				
1-24	91	59 (64.8)	32 (35.2)	<0.001*
25-75	13	0 (0.0)	13 (100)	
Pupils				
ER	78	59 (75.6)	19 (24.3)	<0.001*
NR	7	0 (0.0)	7 (100)	
UR	19	0 (0.0)	19 (100)	
EDH				
No	81	53 (65.4)	28 (34.6)	0.001*
Yes	23	6 (26)	17 (74)	
SDH				
No	59	34 (57.6)	25 (42.4)	0.833
Yes	45	25 (55.5)	20 (44.5)	
SAH				
No	45	32 (71.1)	13 (28.9)	0.01*
Yes	59	27 (45.7)	32 (54.3)	

ISS-Injury severity score; GCS-Glasgow Coma Scale; ER-Equally reactive; NR-Non reactive; UR-Unequally reactive; EDH-Epidural Hemorrhage; SDH-Sub Dural Hemorrhage; SAH- Sub Arachnoid Hemorrhage; *-0.05

Statistical analysis

Data were entered into Microsoft Excel data sheet and were analyzed using the Statistical Package for the Social Sciences (SPSS) 22 version software, International Business Machines Corporation (IBM), Armonk, New York. Categorical data were represented in the form of frequencies and proportions. Chi-square test was used as a test of significance for qualitative data. Continuous data were represented as mean and standard deviation. Graphical representation of data: MS Excel and MS Word were used to obtain various types of graphs such as bar diagram, pie diagram, and ROC curve. *P* value (probability that the result is true) of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

Results

The prospective observational study included 104 TBI patients with age more than 60 years over a period of
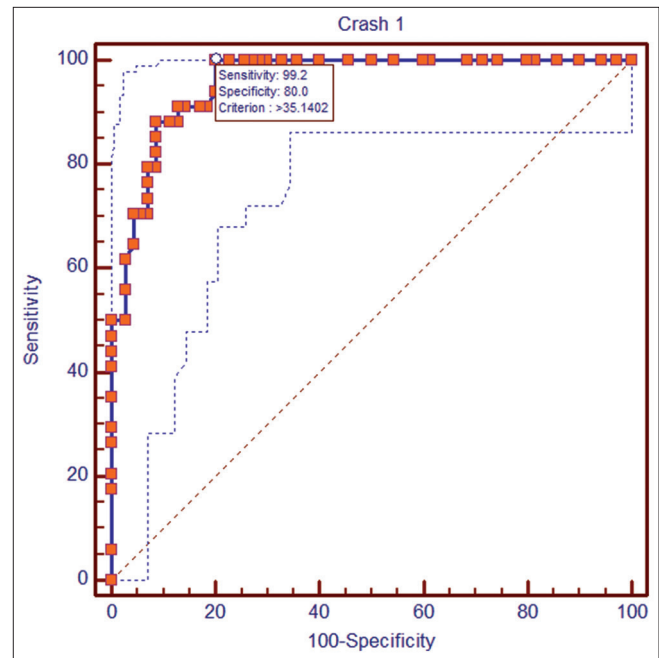
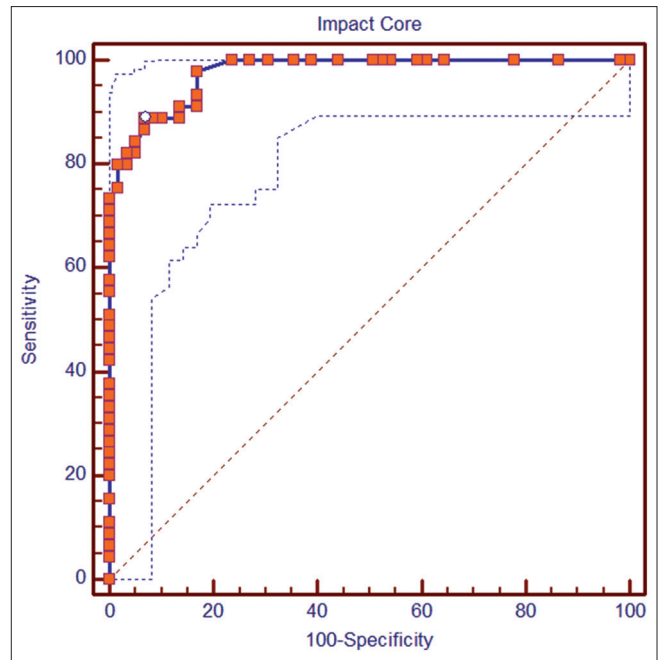**Graph 2: Receiver operator characteristic curve showing validity of CRASH score in predicting mortality at 14 days**

Table 6: Performance measures of the prognostic models in predicting mortality

| Model	Criterion	Sensitivity	Specificity	PPV	NPV	AUC	Youden index	*P*
Mortality at discharge								
TRISS	≤88	94.12	80.00	69.6	96.6	0.95	0.7412	<0.0001
Mortality at 14 days								
CRASH	>35	100.00	80.00	70.8	100.0	0.958	0.8000	<0.0001
Mortality at 6 months								
CRASH	>84	88.24	88.57	78.9	93.9	0.959	0.7681	<0.0001
IMPACT (core)	>38	88.89	93.22	90.9	91.7	0.976	0.8211	<0.0001
IMPACT (extended)	>27	91.11	89.83	87.2	93.0	0.968	0.8094	<0.0001
IMPACT (lab)	>41	82.22	100.00	100.0	88.1	0.954	0.8222	<0.0001

AUC-Area under the curve; PPV-Positive predictive value; NPV-Negative predictive value; TRISS-Trauma and injury severity score; IMPACT-International Mission on Prognosis and Analysis of Clinical Trials; CRASH-Corticoid Randomisation After Significant Head injury
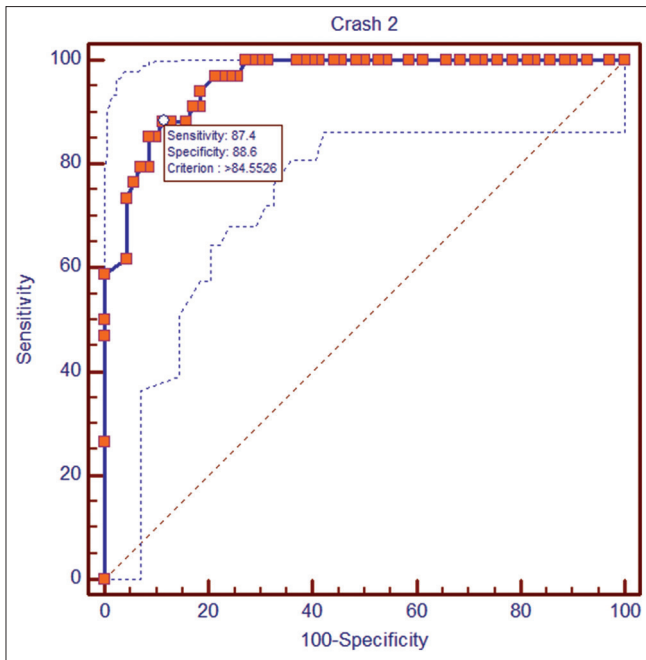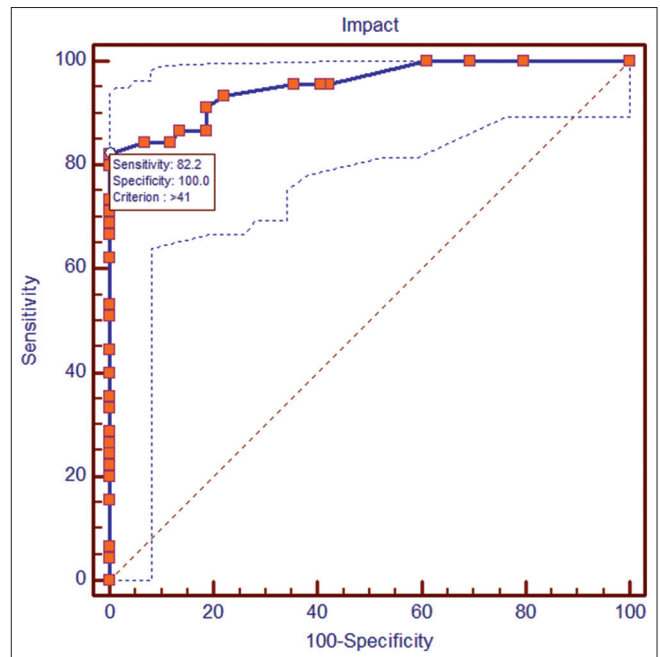
Graph 3: Receiver operator characteristic curve showing validity of CRASH score in predicting mortality at 6 months

Graph 4: Receiver operator characteristic curve showing validity of IMPACT (core) score in predicting mortality at 6 months
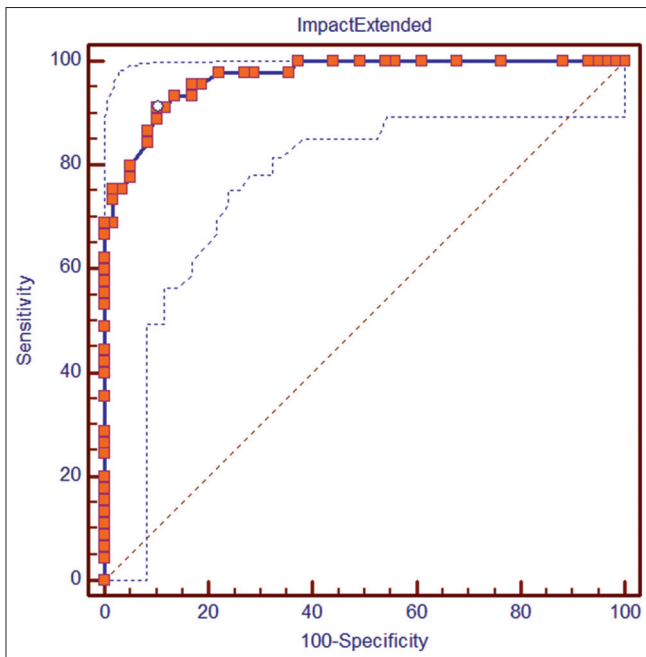
Graph 5: Receiver operator characteristic curve showing validity of IMPACT (extended) score in predicting mortality at 6 months

Graph 6: Receiver operator characteristic curve showing validity of IMPACT (lab) score in predicting mortality at 6 months

18 months following road traffic accident. Of the total 80 were in the age group of 60–70 years, 21 were in 70–80 years and only 3 were in more than 80 years. About 72.1% were men (n = 75) and 27.9% were women (n = 29). Fifty patients had oral intubation following emergency department arrival due to low GCS. Thirty-five had mortality at the time of discharge and 45 at the end of 6 months. Patients' demographic and

clinical characteristics are shown in Table 3. The tested variables such as patients' age, GCS score, pupillary reaction, and the ISS at admission were all significantly associated with mortality at discharge and at the end of 6 months (P < 0.0) [Table 4 and 5].

The predictive accuracies of the TRISS, CRASH, and IMPACT were calculated using ROC curves for the prediction of mortality. Best cutoff points for predicting
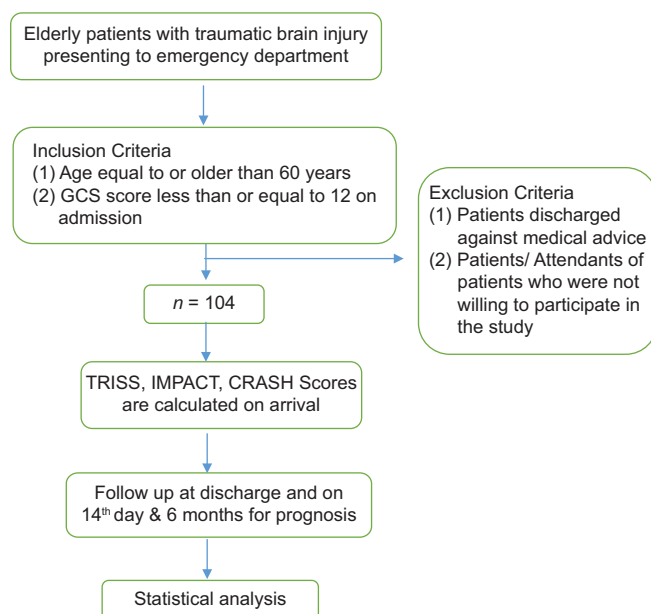
Figure 1: : Flow chart depicting research methodology

mortality in elderly TBI patients in TRISS, CRASH at 14 days, CRASH at 6 months, IMPACT (core), IMPACT (extended), and IMPACT (lab) models were ≤88, >35, >84, >38, >27, and >41 with sensitivity of 94%, 100%, 88%, 88%, 91%, and 82% and specificity of 80%, 80%, 88%, 93%, 89%, and 100%, respectively [Table 6].

The area under the ROC curve was 0.95 in TRISS, 0.958 in CRASH at 14 days, 0.959 in CRASH at 6 months, and 0.976, 0.968, and 0.954 in IMPACT score core, extended, and lab models, respectively, at the end of 6 months [Graphs 2-6]. The Youden index was 0.7412 in TRISS, 0.800 in CRASH at 14 days, 0.7681in CRASH at 6 months, and 0.8211, 0.8094, and 0.8222 in IMPACT score core, extended, and lab models, respectively, at the end of 6 months. All models showed a good ability to discriminate between survival and death at discharge and at 6 months as indicated by values of area under the curve (AUC) and Youden index [Table 6].

Discussion

The main aim of the present study was the applicability of TRISS, CRASH, and IMPACT models in the elderly with moderate-to-severe TBI for mortality prediction. In the present study, the AUC for mortality prediction using the TRISS, CRASH (CT), and IMPACT models was 0.95 (TRISS), 0.958 (CRASH at 14 days), 0.959 (CRASH at 6 months), and 0.976, 0.968, and 0.954 (IMPACT core, extended, and lab at 6 months, respectively).

In Maeda *et al*'s study, the AUC for mortality prediction using the TRISS, CRASH (CT), and IMPACT models was 0.75 (TRISS), 0.86 (CRASH at 6 months), and

0.81 and 0.85 (IMPACT core and extended at 6 months, respectively).[14] In Wan *et al*'s study, the AUC for mortality prediction using the IMPACT core, extended, and lab models was 0.76, 0.76, and 0.73, respectively.[15] In Han *et al*'s study, the AUC for mortality prediction using the CRASH and IMPACT ranged from 0.80 to 0.89.[11] Our study results indicates that the AUC for mortality prediction using the TRISS, CRASH (CT), and IMPACT was significantly high when compared with the other studies.

Conclusion

Our study findings suggest that TRISS, CRASH, and IMPACT models have good values for prediction of mortality in the elderly with moderate-to-severe TBI. However, IMPACT (core and extended) model has maximum prediction in mortality when compared with the other models.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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