Predicting Outcomes in Patients with Diffuse Axonal Injury: External Validation of the Widely Used Prognostic Instruments

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AIM: Accurate prognosis of diffuse axonal injury (DAI) is important in directing clinical care, allocating resources appropriately, and communicating with families and surrogate decision-makers.
METHODS: A study was conducted on patients with clinical DAI due to closed-head traumatic brain injury treated at a trauma center in Brazil from July 2013 to September 2015. The objective efficacy of the Glasgow Coma Scale (GCS), Trauma and Injury Severity Scoring system (TRISS), New Trauma and Injury Severity Scoring system (NTRISS), Abbreviated Injury Scale (AIS)/head, Corticosteroid Randomization After Significant Head Injury (CRASH), and International Mission on Prognosis and Analysis of Clinical Trials (IMPACT) models in the prediction of mortality at 14 days and 6-months and unfavorable outcomes at 6 months was tested.
RESULTS: Our cohort comprised 95 prospectively recruited adults (85 males, 10 females, mean age 30.3 $\pm$ 10.9 years) admitted with DAI. Model efficacy was assessed through discrimination (area under the curve [AUC]), and Cox calibration. The AIS/head, TRISS, NTRISS, CRASH, and IMPACT models were able to discriminate both mortality and unfavorable outcomes (AUC 0.78–0.87). IMPACT models resulted in a statistically perfect calibration for both 6-month outcome variables; mortality and 6-month unfavorable outcome. Calibration also revealed that TRISS, NTRISS, and CRASH systematically overpredicted both outcomes, except for 6-month unfavorable outcome with TRISS.
CONCLUSIONS: The results of this study suggest that TRISS, NTRISS, CRASH, and IMPACT models satisfactorily discriminate between mortality and unfavorable outcomes. However, only the TRISS and IMPACT models showed accurate calibration when predicting 6-month unfavorable outcome.

Keywords: diffuse axonal injury; trauma systems; cohort study; outcome of injury; prognostic models

Introduction

Diffuse axonal injury (DAI) is characterized by rapid progression to coma following angular or rotational acceleration-deceleration forces to the brain. Clinical diagnostic criteria for DAI include loss of consciousness for more than six hours following closed-head traumatic brain injury (TBI) [1, 2, 3, 4]. Moreover, neuroimaging criteria, with several focal white matter lesions measuring 1–15 mm in a characteristic distribution, and anatomopathological markers can help properly classify DAI [5, 6, 7]. Previous research has demonstrated that the duration of coma is strongly associated with poor outcomes and death after DAI and that other indications of TBI severity (e.g., Glasgow Coma Scale [GCS] score or other more comprehensive predictive algorithms) may refine predictive ability [8, 9, 10].

The Abbreviated Injury Scale (AIS) is an anatomical scoring system, that examines nine separate body regions, including the head (AIS/head), and ascribes an injury severity score to each of them, ranging from 1 (minor) to 6 (maximal) [4, 8, 9, 10, 11]. The Injury Severity Score (ISS) is a measure derived from the AIS that produces a single score that is widely used in trauma to predict mortality [12, 13]. It is derived by focusing exclusively on the

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three most severely injured regions as documented by the AIS and adding the severity scores for those regions using a sum-of-squares approach. The New Injury Severity (NISS) was created in an attempt to more precisely predict patient mortality by compensating for one of the limitations of the ISS—its insensitivity to multiple severe lesions in one region [14]. Instead of focusing on three separate body regions, the NISS focuses on the three worst bodily injuries, irrespective of location [14].

The Trauma and Injury Severity Scoring system (TRISS) [15] uses patient age, ISS, and their Revised Trauma Score (RTS), to estimate the probability of survival for two types of trauma: blunt and penetrating. The New Trauma and Injury Severity Scoring system (NTRISS) is a modified version of the TRISS that considers the NISS instead of ISS in the calculation method [16]. Although some studies [16, 17] demonstrate superior prognostic accuracy for the NTRISS compared to the TRISS, other studies do not [18, 19].

The Corticosteroid Randomization After Significant Head Injury (CRASH) and International Mission on Prognosis and Analysis of Clinical Trials (IMPACT) models are the most recent addition to the prognostic armamentarium in TBI and have been prospectively validated in multiple large studies [20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30]. It is a scale specific to brain injury. The CRASH and IMPACT models have consistently shown satisfactory discrimination in predicting unfavorable outcomes and mortality after severe brain injury when externally validated with data from high-income countries [29, 30] and in a South American cohort [26].

We hypothesized that GCS, AIS/head, TRISS, NTRISS, CRASH and IMPACT models could be used for prediction of 14-day mortality, 6-month mortality and 6-month unfavorable outcome in patients with DAI and to externally evaluate the efficacy of those models.

Materials and Methods

Patient Selection

This was a prospective inception cohort study, performed at a Level 1 trauma center in São Paulo, Brazil. The study represents a subset of 296 consecutively screened patients with severe TBI who were admitted between July 2013 and September 2015. This study was approved by the Research Ethics Committee of the University of São Paulo School of Nursing, São Paulo, Brazil (number: 1.595.952) (in accordance with the Helsinki Declaration). All participants or their legal representatives freely consented to participation and signed the informed consent.

Criteria for participation in the study included age 18–60 years, having experienced a closed head TBI, being admitted less than six hours after injury, and a GCS score $\leq$8 at hospital admission. Exclusion criteria included a history of previous moderate or severe TBI, decompressive craniectomy, serious psychiatric, neurologic, or systemic illness that would be expected to alter recovery, concurrent spinal cord injury with an AIS severity $\geq$3 [4], or significant social impediments that would make follow up unlikely. Patients transferred from other health services were also excluded as in most cases we could not reliably verify essential study variables such as treatments received and initial time of injury. A patient flow diagram is provided in Fig. 1. We used Microsoft PowerPoint 2021 (Microsoft Corporation, Redmond, WA, USA) to create Fig. 1.

DAI was defined as loss of consciousness for more than 6 hours after closed-head traumatic brain injury confirmed by a radiological image showing several focal white-matter lesions measuring 1–15 mm in a characteristic distribution.

Data Collection

Relevant sociodemographic, medical, and trauma histories were extracted from the clinical chart and corroborated with family and/or patient interviews. Patients were followed daily and all clinical data from the hospital stay, including computed tomography (CT) scans, were collected prospectively from the clinical record until death (N = 24) or discharge (N = 71). Discharge disposition in the year after injury was as follows: 17 to rehabilitation services, 48 to home, and 6 transferred to another hospital.

Details Regarding Prognostic Models

DAI was classified as mild, moderate, or severe according to page 51 of the AIS classification system manual classification system [4]. Mild was defined as recovery of coma between 6–24 hours, moderate as coma >24 hours without brainstem signs [that is, decerebrate and decorticate posturing], and severe as coma >24 hours with brainstem signs [3, 4].

To calculate the survival probability (SP) as indexed by the TRISS or NTRISS we used the following formula:

$$SP = 1/(1 + e^{-b})$$

where, for blunt trauma, b = (–0.4499) + [0.8085 (RTS)] + [–0.0835 (ISS or NISS)] + [–1.7430 (age index)] [15]. The covariate age index is equal to 0 for patients $\leq$54 years and 1 for those over 54 years. As per convention, the ISS was used to compute the TRISS score, whereas NISS was used for NTRISS. The SP of both TRISS and NTRISS are given as percentage values ranging from 0 to 100%, with higher scores representing greater chances of survival [15, 16, 17]. The related probabilities of mortality and unfavorable outcome are obtained by calculating 1–SP and can also be reported as percentages.

For grading the AIS we did not consider bodily injury; only the severity of head injury was used and was ranked on an ordinal scale of 1 to 6, where 1 represents mild injury and 6 is the most severe [4].

The web-based prognosis calculator, which was built by the authors of the CRASH computed tomography (CT) prognostic model [20], and IMPACT [21] were used to estimate the probabilities of 14-day mortality, 6-month mor-

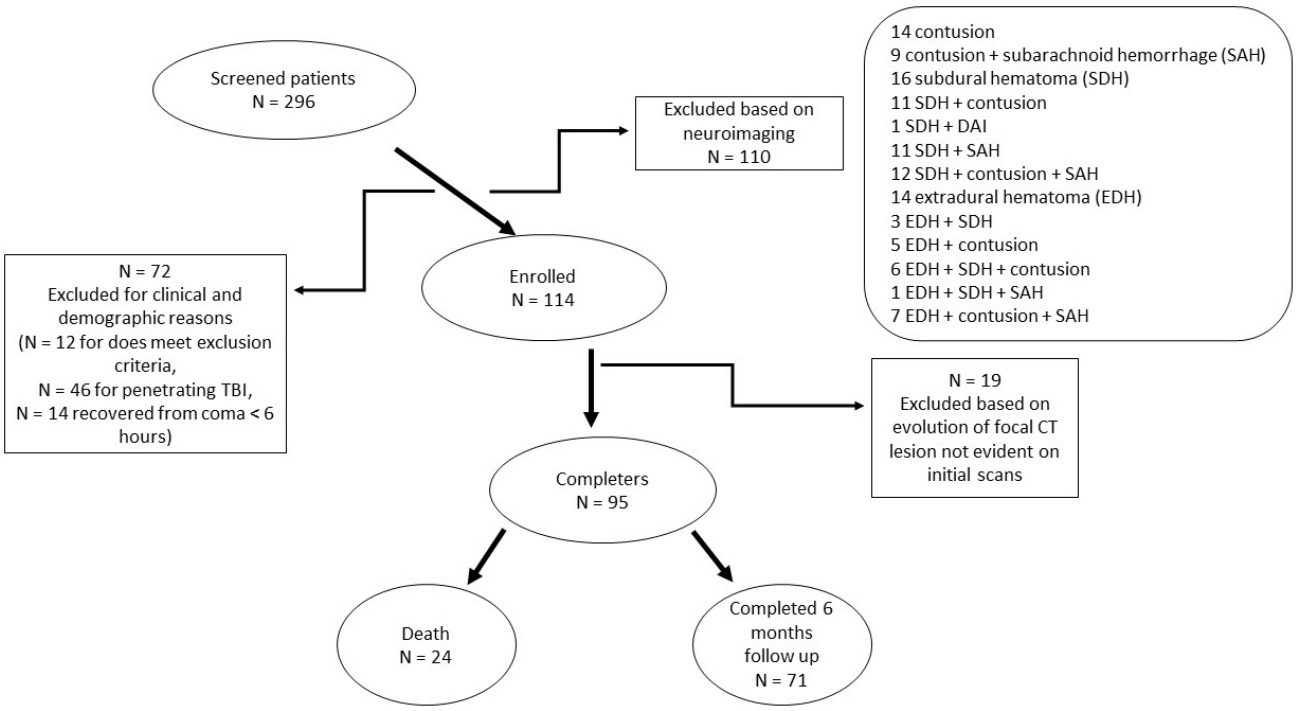

Fig. 1. Patient flow diagram. TBI, traumatic brain injury; DAI, diffuse axonal injury; CT, computed tomography.

tality, and 6-month unfavorable outcome for the patients in our cohort. Corticosteroid Randomization After Significant Head Injury computed tomography model (CRASH CT) probabilities were calculated considering the model for low-middle income countries and the presence of imaging variables (petechial hematoma, obliteration of basal cisterns or the third ventricle, subarachnoid hemorrhage, midline shift, and non-evacuated hematoma) [20].

Outcome

The GOS score was initially recorded by the surgical trauma team upon admission to the hospital. GOS score is a five-point ordinal scale ranging from (1) Death, (2) Vegetative State, (3) Severe Disability, (4) Moderate Disability, (5) Good Recovery [31, 32]. For reporting outcomes at 6 months, the categories of the GOS were dichotomized into unfavorable outcomes (1 to 3) and favorable outcomes (4 or 5) [31, 32].

Data Analysis

In Table 1 categorical variables are described with absolute and relative frequencies, whereas mean, and standard deviation (SD) are presented for numerical variables. R 3.4.2 (R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analyses.

Discrimination and calibration were used to assess the performance of the various models. Discrimination is a measure of how well each prognostic tool predicts true patient outcomes. To investigate the discriminatory power of GCS, AIS/head, TRISS, NTRISS, CRASH, and IMPACT models, an area under the receiver operating characteristic (ROC) curve analysis [33] was performed to obtain the following metrics: area under the curve (AUC) and its 95% bootstrap-based confidence interval; sensitivity; specificity; positive predictive value (PPV) and negative predictive value (NPV).

Calibration is a logistic regression-based technique used to measure how well the predicted outcome probabilities match the observed probabilities and, therefore, can only be applied to TRISS, NTRISS, CRASH, and IMPACT models as GCS and AIS/head are not probability-based prognostic models. Calibration of TRISS, NTRISS, CRASH, and IMPACT models was done considering the intercept and slope of the Cox calibration as this approach has shown the highest statistical power to detect poor calibration in an external model validation [34].

Although the results for TRISS and NTRISS are commonly presented in terms of probability of survival, to facilitate comparisons with the CRASH and IMPACT models we considered in our analyses the probability of mortality/unfavorable outcome, which is one minus the probability of survival.

Results

Study Population

From the total of 296 patients admitted between July 2013 and September 2015, 95 severe TBI patients with DAI completed the 6-month follow-up. The mean age of participants was 30.3 $\pm$10.9 years and the majority were male (85 males, 89.5%). The main cause of DAI was motor vehicle

crashes (86.3%). The most frequent victims of motor vehicle crashes were motorcyclists (46.3%), followed by automobile occupants (27.4%), and pedestrians (10.5%). Falls (7.4%) and other causes (6.3%) were responsible for the remaining injuries. Coma duration was greater than 24 hours in 56.8% of the patients.

The mean ISS of all patients was 34.4 (Standard deviation [SD] = 10.8), and 82.1% were categorized as severely injured (ISS $\geq$25). The mean NISS was 44.3 (SD = 14.3) with 92.6% categorized as severely injured (NISS $\geq$25). The mean AIS/head score was 4.5 (SD = 0.5) with 53.7% having sustained a "critical injury" to the head (AIS = 5). The mean RTS score was 4.7 (SD = 1.3). TRISS mean mortality probability (1–SP) was 40.4% (SD = 28.3%) and for NTRISS it was 53.7% (SD = 30.8). The CRASH CT mean probabilities for 14-day mortality and 6-month unfavorable outcomes were 36.96% (SD = 18.7%) and 71.7% (SD = 16.8%), respectively. The IMPACT Extended model mean probabilities for 6-month mortality and 6-month unfavorable outcome were 23.3% (SD = 14.3%) and 40.0% (SD = 17.4%), respectively. For the IMPACT Lab model, the mean probabilities for 6-month mortality and 6-month unfavorable outcome were 20.7% (SD = 14.6%) and 37.4% (SD = 19.2%), respectively.

Eighty-nine patients (94.7%) were admitted to the intensive care unit (ICU) where they stayed for a mean of 13.4 $\pm$ 16.2 days with only 4 patients monitored for intracranial pressure. The mean hospital length of stay was 19.3 $\pm$ 21.1 days). Neuroimaging characteristics of those patients (N = 17) who died within 14 days included petechial hemorrhages in 7 patients, effaced basal cisterns in 8 patients, subarachnoid blood in 12 patients, midline shift in 1 patient while 3 patients had no acute traumatic findings visible on CT scan. Patient characteristics and CRASH CT and IMPACT prognostic modeling outcomes are further described in Table 1.

Prognostic Models

Discrimination

Of the models considered, NTRISS had the most discriminatory power (AUCs = 0.87 and 0.86) and GCS the least (AUCs = 0.62 and 0.61) when predicting both 14-day mortality and 6-month unfavorable outcomes. TRISS, NTRISS, and CRASH CT showed satisfactory discriminatory power (AUC $\geq$0.8) for 14-day mortality. The IMPACT Extended model showed higher AUC than IMPACT Lab (AUCs = 0.83 and 0.80). When comparing the ability to predict 6-month unfavorable outcomes, AIS/head, TRISS, and NTRISS models showed satisfactory discrimination (AUC $\geq$0.8). Comprehensive results are detailed in Table 2.

Calibration

Cox calibration for TRISS, NTRISS, CRASH CT, and IMPACT models are shown in Table 2. For 14-day mortality, Cox calibration resulted in intercepts that are statistically lower than zero for TRISS, NTRISS, CRASH CT, which indicates that all models overpredicted the probability of 14-day mortality. When considering 6-month unfavorable outcomes, Cox calibration also revealed that NTRISS and CRASH overestimated the probability of 6-month unfavorable outcomes; however, TRISS calibration had an intercept that was not significantly different than zero, which indicates that its predicted probabilities of 6-month unfavorable outcomes do closely match the observed values. IMPACT Lab and IMPACT extended models also resulted in calibration intercepts that were not significantly different from zero when predicting both 6-month mortality and 6-month unfavorable outcomes. Regarding the slopes, the calibration analysis showed that they are not significantly different from one in any case, which indicates a good degree of spread in the predicted probabilities over the zero-to-one range from all models and all possible outcomes.

Discussion

We externally validated GCS, AIS/Head, TRISS, NTRISS, CRASH CT and two IMPACT prognostic models for the prediction of 14-day mortality, 6-month mortality, and 6-month unfavorable outcome in a cohort of patients in Brazil. We found good discrimination in almost all models, consistent with other validation studies [26, 35]. Using Cox calibration, we identified the overestimation of 14-day mortality when using TRISS, NTRISS, and CRASH CT and also the overestimation of 6-month unfavorable outcomes when using NTRISS and CRASH CT. IMPACT Lab and extended models led to statistically perfect calibration for both 6-month mortality and 6-month unfavorable outcomes. This was somewhat surprising and counter to our original hypothesis that these models would tend to underpredict poor outcomes in our lower-resourced environment. The reasons are speculative but might include the fact that GCS is a significant predictor of outcome for TRISS, NTRISS, CRASH and IMPACT models (with lower values of GCS leading to poorer outcomes) [15, 16, 20].

In a recent systematic review [28] that included 58 studies reporting on the development, validation or extension of prognostic models after moderate and severe TBI, Dijkland *et al*. [28] showed variation in the discrimination ability of the models predicting mortality (AUC ranged from 0.71 to 0.94 for internal validation, and from 0.61 to 0.99 for external validation) and unfavorable outcome (AUC ranged from 0.66 to 1.00 for external validation). Their calibration results also exhibited substantial variation in the agreement between observed and predicted probabilities, the mean weighted calibration intercept was –0.28 (ranging from –3.3 to +0.93) for the models for mortality, and –0.019 (ranging from –5.7 to +2.4) for the models for unfavorable outcome, while the mean weighted calibration slopes were 1.1 (ranging from 0.42 to 2.3) and 0.88 (ranging from 0.57 to 2.5) for mortality and unfavorable outcome, respectively [28].

Table 1. Demographic and injury characteristics in patients with traumatic axonal injury (N = 95).

Indicators	Value
Age (years), mean ± SD	30.3 ± 10.9
Sex – n° (%)	
Female	10 (10.5)
Male	85 (89.5)
GCS score – n° (%)	
3	46 (48.4)
4–5	11 (11.6)
6–7	32 (33.7)
8	6 (6.3)
Motor score of GCS at admission – n° (%)	
None	47 (49.5)
Extension	5 (5.3)
Abnormal flexion	12 (12.6)
Normal flexion	28 (29.4)
Localises/obeys	3 (3.2)
Untestable or missing	-
Pupils – n° (%)	
Both nonreactive	16 (16.8)
One reactive	7 (7.4)
Both reactive	72 (75.8)
Marshall CT scan classification – n° (%)	
Diffuse injury I	22 (23.1)
Diffuse injury II	68 (71.6)
Diffuse injury III	5 (5.3)
CT scan brain appearance – n° (%)	
Presence of petechial hemorrhages	30 (31.6)
Effaced basal cisterns	14 (14.7)
Subarachnoid blood	45 (47.4)
Midline shift	2 (2.1)
Non-evacuated haematoma	95 (100)
Hb (g/dL)	Average 12.3 (SD = 2.4)
Anaemia (Hb <8 g/dL) – n° (%)	6 (6.3)
Glucose (mg/dL)	Average 151.4 (SD = 58.8)
Hypoglycaemia (Glucose <80 mg/dL)	3 (3.2)
Hyperglycaemia (Glucose <180 mg/dL)	19 (20.0)
PO_2 (mmHg)	Average 195.9 (SD = 117.7)
Hypoxia – n° (%)	10 (10.5)
Hypotension – n° (%)	17 (17.9)
Hypertension – n° (%)	11 (11.5)
Outcomes – n° (%)	
14-day mortality	17 (17.9)
6-month mortality	24 (25.3)
6-month unfavorable outcome	32 (33.8)

Hb, hemoglobin; CT, computed tomography; GCS, Glasgow Coma Scale; PO_2, partial pressure of oxygen; SD, Standard deviation.

Several other studies have investigated the prediction of mortality and unfavorable outcomes by TRISS, CRASH, and IMPACT in trauma and TBI populations [20, 21, 22, 23, 24, 25, 26, 28, 29, 30], some of these studies showed different results of calibration in populations with severe TBI. However, two prior TBI studies, by Wong *et al*. [24] in a Hong Kong sample and Maeda *et al*. [27] in a Japan sample, have compared the TRISS, CRASH and IMPACT models. Maeda *et al*. [27] showed satisfactory discrimination for the prediction of unfavorable outcomes (AUC ranging from 0.81 to 0.86) by CRASH and IMPACT models in patients with severe TBI, but lower AUC (0.75) for predi-

Table 2. Performance of the GCS, AIS/head, TRISS, NTRISS, CRASH and IMPACT models for prediction of mortality and unfavorable outcomes after traumatic axonal injury.

Outcome	Models	AUC (95% CI)	Sensitivity %	Specificity %	PPV %	NPV %	Cox intercept (95% CI)	Cox slope (95% CI)
14-day mortality	GCS	0.62 (0.47, 0.78)	82.3	51.3	26.9	93.0		
	AIS/head	0.78 (0.69, 0.87)	100.0	56.4	33.3	100.0		
	TRISS	0.82 (0.71, 0.93)	76.5	75.6	40.6	93.6	–1.61 (–2.24, –0.98)	0.79 (0.37, 1.2)
	NTRISS	0.87 (0.77, 0.97)	82.3	83.3	51.8	95.6	–2.69 (–3.69, –1.68)	0.93 (0.51, 1.36)
	CRASH CT	0.84 (0.70, 0.97)	88.2	78.2	46.9	96.8	–1.08 (–1.71, –0.44)	1.77 (0.93, 2.61)
6-month mortality	IMPACT Ext.	0.83 (0.72, 0.94)	79.2	85.9	65.5	92.4	0.86 (–0.12, 1.83)	1.72 (0.89, 2.56)
	IMPACT Lab	0.80 (0.68, 0.91)	66.7	87.3	64.0	88.6	0.88 (–0.16, 1.91)	1.47 (0.74, 2.21)
6-month unfavorable outcome	GCS	0.61 (0.48, 0.73)	71.9	54.0	44.2	79.1	-	-
	AIS/head	0.83 (0.74, 0.90)	96.9	68.3	60.8	97.7	-	-
	TRISS	0.80 (0.70, 0.90)	65.6	82.5	65.6	82.5	–0.45 (–0.96, 0.07)	0.91 (0.5, 1.33)
	NTRISS	0.86 (0.78, 0.95)	81.2	85.7	74.3	90.0	–1.36 (–2.01, –0.72)	0.99 (0.58, 1.4)
	CRASH CT	0.78 (0.68, 0.89)	62.5	92.1	80.0	82.9	–2.35 (–3.28, –1.41)	1.3 (0.72, 1.88)
	IMPACT Ext.	0.76 (0.65, 0.87)	65.6	88.9	75.0	83.6	–0.18 (–0.69, 0.34)	1.53 (0.78, 2.27)
	IMPACT Lab	0.74 (0.63, 0.86)	62.5	84.1	66.7	81.5	–0.1 (–0.64, 0.43)	1.22 (0.6, 1.84)

AIS, Abbreviated Injury Scale; AUC, area under the curve; CI, Confidence Interval; CRASH CT, Corticosteroid Randomization After Significant Head Injury computed tomography model; GCS, Glasgow Coma Scale; IMPACT Ext., International Mission on Prognosis and Analysis of Clinical Trials Extended model; IMPACT Lab, International Mission on Prognosis and Analysis of Clinical Trials Laboratory model; NPV, negative predictive value; NTRISS, New Trauma and Injury Severity Scoring system; PPV, positive predictive value; TRISS, Trauma and Injury Severity Scoring system.

cting mortality in hospital. Wong *et al*. [24] found that all models showed excellent discrimination for 14-day survival (AUC 0.92 for TRISS), 14-day mortality (AUC 0.89for CRASH), 6-month mortality (AUC 0.80 for IMPACT), 6-month survival (AUC 0.91 for TRISS) and 6-month unfavorable outcome (AUC 0.89 for CRASH and AUC 0.81 for IMPACT). Calibration showed that CRASH and IMPACT models overpredicted the probabilities of 14-day mortality, 6-month mortality, and 6-month unfavorable outcome and that TRISS models underpredicted the probabilities of 14-day survival and 6-month survival, that is, TRISS models overpredicted both 14-day and 6-month mortality probabilities [24].

Overprediction of outcomes, as observed in the CRASH and IMPACT models, could potentially lead to incorrect clinical decisions. For instance, if the model overestimates the likelihood of mortality or unfavorable outcomes, clinicians might choose more aggressive treatments that may not be necessary. Alternatively, they might withhold interventions due to an inaccurately grim prognosis. This phenomenon is known as the "self-fulfilling prophecy", a common issue when treating severe neurological diseases in the acute phase, where treatment is often withheld based on prognostic predictions. TRISS and IMPACT models showed perfect calibration for predicting 6-month unfavorable outcomes in our study. Although our patients with DAI had a fair number of multiple body injuries (mean number of injuries per patient 15.0 and SD 8.0) and severe head injury (AIS mean 4.5), it is interesting that only TRISS, and not NTRISS, showed good calibration. Since NTRISS was specifically designed to better integrate co-occurring severe injuries across multiple body systems, a plausible reason for the worse performance of NTRISS may be that most of our patients (85.3%) did not have life-threatening severe injuries (AIS $\leq$3) in other parts of the body (face, chest, abdomen or extremities) [4, 36, 37, 38]. Also, the IMPACT Extended and IMPACT Lab use of a combination of clinical findings, CT classification, and laboratory exams could have contributed to the model's predictive ability. Similarly to our results, Han *et al*. [30] and Wongchareon *et al*. [26] showed via Cox calibration a strong agreement between observed and predicted outcomes.

This study compares the GCS, TRISS, NTRISS, CRASH and IMPACT models in a cohort diagnosed with DAI strictly by CT and clinical criteria. Some limitations should be considered. Our patients are from a single institution, which is a reference center for high-complexity cases in Latin America, and therefore our results cannot be generalized across other hospitals in the same region. The availability of diagnostic resources, particularly in low-resource environments, can be a limitation in treating and diagnosing those patients. Only a small group of patients (34.7%) underwent magnetic resonance imaging (MRI) in follow-up, which limits our ability to validate our original diagnosis of DAI. In counterpoint, in 5 out of 25 cases where the CT scan was normal, the MRI did demonstrate pathology consistent with DAI and for those cases where the initial CT scan showed a positive finding, no cases showed a change in diagnosis after subsequent MRI. A clear strength of this study is the complete follow-up at 6 months of all participants, reducing the amount of missing data and avoiding bias in the patient outcomes.

Conclusions

The results of this study suggest that TRISS, NTRISS, CRASH and IMPACT models satisfactorily discriminate between mortality and unfavorable outcomes in Brazil. However, only TRISS, IMPACT Extended and IMPACT Lab models showed accurate calibration when predicting 6-month unfavorable outcome.

Availability of Data and Materials

The data that support the findings of this study are available on request from the corresponding author.

Author Contributions

The study was conceived, designed, acquisition of data, analyzed and interpreted data by RCAV, RMCS, WJP. Data were acquired, analyzed, and interpreted by WSP, LZP, DVO, DAG, CPES, JLS. Statistical expertise was provided by CPES. The article was drafted by RCAV, RMCS, WSP, LZP, DVO, DAG. Supervision was provided by WJP. All authors revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki. Approval was obtained from the Research Ethics Committee of the University of São Paulo School of Nursing, São Paulo, Brazil (number: 1.595.952), and informed consent was obtained from all participants prior to their involvement in the study.

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Conflict of Interest

The authors declare no conflict of interest.

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