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Long-term outcome of traumatic brain injury patients with initial GCS of 3–5

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1. Introduction

Traumatic brain injury (TBI) is globally prevalent, with significant negative socioeconomic impact.[1] Among patients with severe TBI, those with a Glasgow Coma Scale (GCS) score of 3–5 points at admission (now called "critical") have a higher risk of death and poor functional outcomes.[2] To date, this patient group has not received adequate attention in the literature, and as a result, has not been fully characterized. Despite the poor initial prognosis at the scene or in hospital, there is still an established percentage of critical TBI patients who can recover to favorable outcomes.[3]

Therefore, owing to the pessimistic prognosis, it is essential to analyze the principal characteristics of patients with critical TBI. Evaluating these patients through an epidemiological study and analyzing their functional recovery may support physicians in allocating medical resources more effectively. This includes determining the aggressiveness of interventions based on predictors of favorable outcomes. These findings can guide healthcare providers in tailoring rehabilitation programs to address the unique needs of these patients. Additionally, providing cautious information about outcomes and rehabilitation possibilities to relatives can facilitate better understanding and decision-making.[3,4]

Even after a long follow-up, several consequences of the traumatic injury still contribute to reduced independence and quality of life.[5] Other studies indicate improvement in neurological outcomes and recovery of critical TBI patients, however, despite this relevance, only a few studies have addressed it in a delayed approach, after 3 or more years[6,7]. The hypothesis is that patients with critical TBI have specific characteristics that affect outcome, and current predictive models for TBI are good for long-term outcome after critical TBI. Hence, this study aimed to analyze the epidemiology and outcome of critical TBI patients and identify predictors of long-term functional neurological outcomes.

2. Method

2.1. Study design, setting, data source, and participants

This retrospective case control study included adult patients with critical TBI who were admitted to a Neurotrauma Unit in Sao Paulo, Brazil, between January 2017 and October 2018. Patients with critical

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severe TBI were defined as those with GCS scores of 3–5 points after fluid resuscitation. The study included all adult patients who were directly referred from the trauma scene. Patients with the following conditions were excluded: a) traumatic spinal cord injury (tSCI); b) non-traumatic intracerebral hemorrhage; c) pregnancy; d) penetrating TBI; e) previous neurologic sequelae; f) previous TBI; g) chronic subdural hematoma.

We applied these selection criteria for exclusion to avoid confounding from heterogeneity since some of them have different prognostic profiles, such as older people, non-traumatic intracerebral hemorrhage, and chronic subdural hematoma.[8,9] Additionally, some pathologies, such as tSCI, pregnancy, penetrating TBI, and previous neurologic sequelae or TBI, may interfere with the assessment of patients' neurological outcomes or result in direct disabilities..[10,11] Furthermore, patients referred from other services to our local hospital were excluded due to the unavailability of medical records from the initial hours of assessment.

In this study, "long-term" was defined as at least three years post-TBI. In the case of surviving patients, long-term data were obtained prospectively from October to November 2021, through direct telephone contact or by speaking with their relatives and caregivers if these patients were unable to respond.

This study was approved by the institutional review board of São Paulo Medical School (protocol number: 4.680.30) and was completed in accordance with national ethical research principles, as revised in in its latest version. To ensure comprehensive reporting of the observational study, the structure of the study report followed the guidelines established in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

2.1.1. Variables of interest and outcome

The variables of interest were obtained from medical records and included demographics (age and sex), trauma characteristics (date, mechanism, number of injuries, and intubation at the scene versus in hospital), and clinical, radiographic, and hospitalization data. The clinical data points at admission were GCS score, pupil size, and reactivity. Pupil size was measured as a categorical variable and classified as dilated, anisocoric, and normal. In addition, blood glucose and hemoglobin levels, coagulopathy, arterial blood pressure, blood oxygen level (SpO_2), and the presence of infections were recorded. The admission head computed tomography (CT) scan assessment included hemorrhage/hematoma (intracerebral, subarachnoid, epidural, and subdural) and effacement of the basilar cisterns. Hospitalization data included neurological surgery, intracranial pressure (ICP) monitoring, and length of hospital stay.

We also evaluated the current predictive models for TBI: Corticosteroid Randomization after Significant Head Injury (CRASH) and International Mission for Prognosis and Analysis of Clinical Trials (IMPACT), in its extended versions (CRASH-CT and IMPACT-CT-Lab, respectively), which are commonly used to assess unfavorable outcomes at 6 months only.[12,13]

Outcomes were assessed at two time points – during hospitalization at the time of death and at long-term follow-up, which began at the time of discharge and continued until the study endpoint (October to November 2021). Patients were evaluated through a telephone interview to assess GOS-E, DRS, return to work and behavioral complaints. The GOS-E score was dichotomized into unfavorable (i.e., death, persistent vegetative state, lower severe disability, and upper severe disability) and favorable (i.e., lower moderate disability, upper moderate disability, good recovery, and full recovery) outcomes based on previous studies.[3] GOS-E was used according to a validated, structured interview to assess functional outcomes.[4] For a sensitive and comprehensive assessment of functional neurological status and its implications, Disability Rating Scale (DRS) was used[6] and, while applying both tools, we obtained the functionality outcome from the interviewees, which we summarized in a quantitative analysis.

2.2. Statistical analysis

Categorical variables are expressed as absolute and relative frequencies and compared using the chi-square test or Fisher's exact test. The normality assumption for the continuous variables was assessed using skewness and kurtosis values, as well as graphical methods. Continuous variables with normal distribution are presented as means and standard deviations and were compared using Student's *t*-test for independent samples. Non-normally distributed continuous variables are presented as medians and quartiles and were compared using the nonparametric Mann–Whitney test. Multiple imputation was used through the standard SPSS tool, with five imputations and one pooled data. We were according to literature recommendations[14] to impute only missing independent variables, i.e., not functional outcomes. We registered the data on the REDCAP® platform.[15]

Binary logistic regression was used to identify outcome predictors. Predictors in the univariate analysis significant at the p-value = 0.10 were included in the binary model, and the results were expressed as odds ratios (OR) and their respective 95% confidence intervals (CIs). Length of hospital and intensive care unit (ICU) stay were considered indirect consequences of TBI severity; therefore, they were not included in the model. IMPACT and CRASH scores were included separately in a different binary model to evaluate the application of these models in a long-term approach rather than using each variable due to sampling limitations. Furthermore, we avoided including both models in one analysis since several variables were common to both models. For multiple tests comparison, to avoid inflating the risk of Type I error, we used the Holm adjustment.[16,17]

All tests were two-tailed, and final p-values <0.05 were considered statistically significant. All analyses were performed using Statistical Package for Social Sciences Software (IBM SPSS Statistics for Windows, version 28.0. Armonk, NY: IBM Corp.) and R (R Core Team (2018)). R: Language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/).

3. Results

3.1. Clinical characteristics

Out of the 171 patients initially screened, 56 were included in the analysis. A flowchart of the recruitment procedure is available in the supplemental file. Among the patients who were excluded, 36 did not meet the inclusion criteria, 40 were referred from other hospitals, 22 had tSCI, 7 met other exclusion criteria, and 10 missed follow-up. Logistical issues such as an unknown discharge destination, homelessness, or erroneous address were the most common reasons for loss to follow-up. Of the 56 patients included, 41 (73.2%) experienced unfavorable outcomes.

The majority of patients included in this study were males (84%) and adults (mean 40; standard deviation [sd] 15.2 years). In 76.8% of cases, intubation was performed at the scene of the incident. 73.2% had multisystem trauma. Traffic accidents (62.5%) and falls (32.1%) were the most common causes of trauma. Among traffic accidents, motorcycle crashes accounted for 40%, followed by pedestrian incidents (31%), car accidents (26%), and bicycle accidents (3%). Falls were categorized into ground level falls (27.8%) and falls from a height greater than 3 m (72.2%). The median length of hospital stay was six days (2.0–51.2 days), and 27 (48.2%) of the patients had infections, with 20 (74.1%) of them having positive hemoculture results. Respiratory tract infections were present in 16 (59.3%) patients, and 12 (44.4%) patients had urinary tract infections.

The majority of patients (92.9%) had a GCS score of 3, with a small percentage having scores of 4 (1.8%) or 5 (5.4%). Pupil size was measured as a categorical variable for dilated, anisocoric, and normal-sized. During admission, arterial hypotension and hypoxia were observed in 21.4% and 30.4% of patients, respectively. The median

blood glucose concentration was 10.7 mmol/L (8.8–13.7), and hemoglobin levels were 12.7 (10.8–14.5). Coagulation parameters indicated a median international normalized ratio (INR) value of 1.17 (1.05–1.44) and a median aPTT value of 1.04 (0.92–1.36).

Subarachnoid hemorrhage was the most common hemorrhage observed via head CT (75.0%), followed by contusion (60.7%), subdural hemorrhage (42.9%), and epidural hemorrhage (23.2%). Edema was present in 44 patients (78.6%). Six variables had missing data: pupil reactivity (9%), ICP monitoring (5%), platelets (5%), hypoxia (2%), SpO2 (2%), and INR (1%).

3.2. Outcome assessment

The most frequent outcome category was death, with a total of 37 patients (66.1%), followed by lower moderate disability (6 patients, 10.7%) and full recovery (6, 10.7%). The distribution of outcomes according to the DRS was similar to that of the GOS-E, with moderate incapacity (8.9%) and no incapacity (10.7%) observed in addition to mortality. Pearson's correlation showed a very strong, inverse correlation between DRS and GOS-E ($\rho = -0.963$; $p < 0.001$).

Among patients with unfavorable outcomes, 30 (73.2%) died within 14 days of hospitalization, another 5 patients in hospital stay, and 2 after discharge. 19 patients survived with disabilities in 13 patients. The median time to death was 3 (2–9) days; the two patients who died after discharge had a median time of survival of 1.8 years. Among the surviving patients, the median duration of follow-up was 4.0 (3.5–4.3) years.

Using DRS categories, we evaluated patients' specific neurological functions and incapacities after trauma and during recovery (Fig. 1). Among the surviving patients, "employability" (13 patients, 68.4%) and "level of functioning" (11 patients, 58%) were the most frequently identified incapacities, as well as "communication ability" (4 patients, 21%), "eye-opening" (2 patients, 10.5%), the cognitive ability for "feeding," "toileting," and "grooming" (2 patients, 10.5%), and "motor response" (1 patient, 5.3%) were cited during the interviews.

To examine the relationship between outcome and known variables, older patients had significantly worse outcomes ($p < 0.001$), and male patients tended to have unfavorable outcomes ($p = 0.094$). Intubation at the scene was not associated with functional outcome ($p = 1.000$) neither was the mechanism of trauma ($p = 0.311$) or the presence of multisystem trauma ($p = 0.428$). Longer intervals of hospital stay were associated with better outcomes ($p = 0.002$): favorable, 39 days (17–63); unfavorable, 4 days (2–23). Infection tended to be associated with worse outcomes ($p = 0.095$) **(**Table 1**).**

In addition, the GCS score tended to significantly differ according to the outcome, with more unfavorable outcomes associated with a GCS score of 3 (97.6%) compared to favorable outcomes (80.0%) ($p = 0.055$). We also observed similar correlations for some variables, such as ICP monitoring (24.4% in the unfavorable group vs. 20% in the favorable group; $p = 1.000$) and surgical intervention (48.8% in the unfavorable group vs. 40% in the favorable group; $p = 0.702$). Higher blood glucose concentrations were associated with worse outcomes ($p = 0.041$): favorable, 9.7 (7.3–10.7); unfavorable, 11.5 mmol/L (9.2–14.5) **(**Table 2**).**

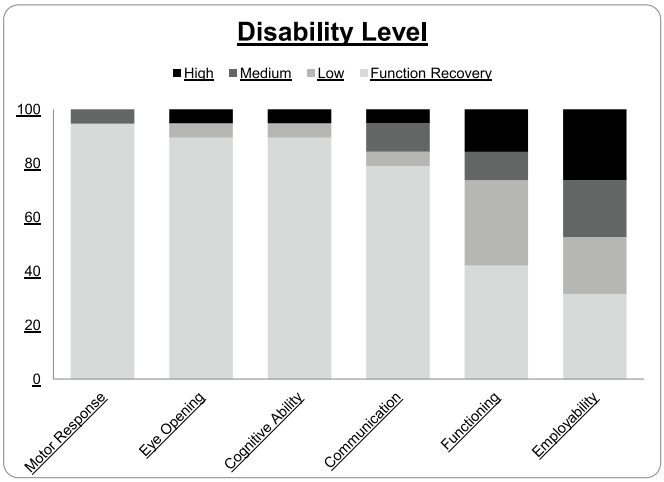

Fig. 1. Disability Rating Scale score in surviving patients.

Table 1
Sample demographic characteristics.

Outcome			
Unfavorable Favorable Parameter ($n = 41$) ($n = 15$)			p value
Age, years	43.6 ± 15.6	30.3 ± 8.6	**<0.001**
Sex, male	32 (78.0)	15 (100.0)	0.094
Trauma mechanism			
Traffic overall	24 (58.5)	11 (73.3)	0.311
MVC, car	6 (14.6)	3 (20.0)	
MVC, motorcycle	7 (17.1)	7 (46.7)	
Pedestrian	10 (24.4)	1 (6.7)	
Fall overall	15 (36.6)	3 (20.0)	0.179
Ground level	3 (7.3)	2 (13.3)	
Height >3 m	12 (29.3)	1 (6.7)	
Other	3 (7.3)	1 (6.7)	
Multisystem trauma, yes	34 (82.9)	14 (93.3)	0.428
Intubation at the scene, yes	31 (75.6)	12 (80.0)	1.000
Infection during hospital stay, yes	17 (41.5)	11 (73.3)	0.095
Length of hospital stay, days	4 (2–23)	39 (17–63)	**0.002**
Length of ICU stay, days	4 (2–14)	30 (7–61)	**0.007**

MVC, motor vehicle collision; ICU, intensive care unit.
Bold values indicate potential significant variables.
Data presented as valid n (%) except for age, indicated as mean ± standard deviation; length of hospital and ICU stay is indicated as median (quartiles).

Table 2
Admission assessment and secondary brain injury data.

Outcome			
Unfavorable Favorable Parameter ($n = 41$) ($n = 15$)			p Value
Hypotension SBP <90 mmHg	11 (26.8)	1 (6.7)	0.149
Glucose (mmol/L)	11.5 (9.2–14.5)	9.7 (7.3–10.7)	**0.041**
Hypoxia, SpO2 <95%	16 (39.0)	1 (6.7)	**0.023**
GCS score = 3	40 (97.6)	12 (80.0)	**0.055**
Pupil reactivity	20 (48.8)	14 (93.3)	**0.003**
Pupil size			**0.044**
Anisocoric	11 (26.8)	3 (20.0)	
Bilaterally dilated	14 (34.1)	1 (6.7)	
Blood parameters			
Hemoglobin	12 (10.3–14)	14 (14–15)	**0.004**
Platelet count	197 ± 66.8	269 ± 52.7	**<0.001**
INR	1.2 (1.1–1.5)	1.1 (1.0–1.2)	**0.042**
INR >1.2	24 (58.5)	3 (20.0)	**0.011**
aPTT	1.1 (1.0–1.4)	1.0 (0.9–1.2)	0.244
aPTT >1.2	16 (39.0)	3 (20.0)	0.183
Radiographic findings			
Hemorrhage			
Subarachnoid	33 (80.5)	9 (60.0)	0.165
Subdural	21 (51.2)	3 (20.0)	**0.037**
Epidural	10 (24.4)	3 (20.0)	1.000
Intraparenchymal	27 (65.9)	7 (46.7)	0.193
Effaced cortical sulci, yes	37 (90.2)	7 (46.7)	**0.001**
Neurosurgical intervention, yes	20 (48.8)	6 (40.0)	0.702
ICP Monitorization, yes	10 (24.4)	3 (20.0)	1.000

SBP, systolic blood pressure; SpO2, blood oxygen level; INR, international normalized ratio; aPTT activated partial thromboplastin time; ICP, intracranial pressure.
Bold values indicate potential significant variables.
Data presented as valid n (%) except for platelet count, indicated as mean ± standard deviation; hemoglobin, and glucose are indicated as median (quartiles).

Significant associations between blood parameters and outcomes were observed, with higher levels of hemoglobin ($p = 0.004$), platelets ($p < 0.001$), and INR levels closer to 1 being associated with better outcomes ($p = 0.042$). Other clinical data, such as pupil reactivity and size, were associated with the outcomes, with the absence of pupil reactivity being found mostly in the unfavorable group (48.8%, $p = 0.003$) and normal pupil size being associated with favorable outcomes ($p = 0.044$) **(**Table 2**).**

Hypoxia was associated with worse outcomes ($p = 0.023$): unfavorable, 39%; favorable, 6.7%. There was no association between outcome and hypotension ($p = 0.149$), neurosurgical intervention ($p = 0.702$), or ICP monitoring ($p = 1.000$). Some radiographic factors showed different frequencies according to the outcome group: except for subdural hematoma ($p = 0.037$), intracranial hemorrhage as subarachnoid ($p = 0.165$), epidural ($p = 1.000$), and intraparenchymal ($p = 0.193$) were not associated with outcome. Most patients with unfavorable outcomes had effacement of the basilar cisterns (90.2%) (p 0.001) **(**Table 2**).**

3.3. Outcome prediction

Table 3 displays the results of the binary logistic regression analysis. Age was found to be a significant predictor of lower odds of favorable outcomes (OR 0.863, 95% CI 0.863–0.990, $p = 0.025$). Hemoglobin level (OR 1.673, 95% CI 1.023–2.736, $p = 0.040$) and platelet count (OR 1.019, 95% CI 1.004–1.033, $p = 0.012$) were also associated with higher odds of favorable outcomes. Age was modeled as a continuous variable, as dichotomization into age 40+ years resulted in a worse model fit. Stepwise selection did not retain any other variables.

Furthermore, we evaluated the application of CRASH and IMPACT in predicting long-term outcomes. Both IMPACT-CT-Lab and CRASH scores predicted outcomes satisfactorily (OR 1.137, CI 95% 1.059–1.220, $p < 0.001$ and OR 1.183, CI 95% 1.080–1.297, $p < 0.001$, respectively). However, the CRASH-CT score exhibited a greater standard error (0.047) compared to the IMPACT-CT-Lab score (0.036).

In Fig. 2, the predicted long-term unfavorable outcome probabilities for CRASH-CT are plotted against the probability predicted by IMPACT-CT-Lab. The IMPACT-CT-Lab score classified patients better than the CRASH-CT score, mainly after 60% of unfavorable outcome probability, whereas CRASH-CT was more reliable only after 85%.

4. Discussion

4.1. Outcome assessment

Our study focuses on patients with TBI and GCS scores of 3–5, a severity range that has been less frequently studied than other severity intervals such as GCS ≤ 8 or GCS $= 3$ [18]. While many studies assess short-term outcomes at discharge or 6–12 months post-TBI,[19–21] our study focuses on long-term outcomes of at least one-year post-TBI, during which mortality rates are high and outcomes are often unfavorable.[22,23]

However, it should be noted that outcome changes are dynamic after large periods (such as 12–14 years), and the outcome appears to decline progressively over time.[24] According to previously reported data, outcomes appear to change only after larger intervals (e.g., years 1–5) rather than annually in a 9-year analysis.[6] These findings indicate the influence of time on the outcome, which may also be related to other factors.

4.2. Outcome predictors

In previous studies on long-term outcome prediction, various factors such as age, trauma severity, basal cistern status, education level, pupil reactivity, presence of hematoma on CT scan, and GOS score at ICU discharge have been described as independent factors,[7,23,25,26] most of which were also included in our results.

Platelet count was an independent predictor, corroborating the relationship between a decreased platelet count and other coagulation parameters (aPTT and INR) with worse outcomes.[27,28] The lower odds ratio for platelet count may indicate an indirect association as platelet hypofunction has been associated with low GCS scores.[29] Similarly, concerning coagulopathies, the use of direct oral anticoagulants (DOACs) or vitamin K antagonists may impact prognosis. Short-term studies suggest that DOACs lead to better outcomes and faster reversal times compared to vitamin K.[30] However, we could not find any studies in literature regarding DOACs usage to assess long-term outcome, or time of usage, which might be relevant information.

Pupillary abnormalities (reactivity and size) are important factors related to mortality in severe TBI patients during hospitalization and long-term follow-up.[23,25,26] However, in our study, both variables were statistically only significant in univariate analysis and were not included in the model after the multivariable analysis.

Age was an independent predictor of outcome, which is consistent with the previous studies indicating that older patients are more likely to have unfavorable outcomes (often observed in short-term follow-ups).[19,20,31] Similarly, Marquez de la Plata et al.[8] reported that, through DRS scores, more disabilities were observed among older patients in the first five years post-TBI, with no difference observed in the first year. These findings highlight the importance of evaluating delayed long-term outcomes.

4.3. Outcome prediction models

Predictive models have demonstrated improved outcomes by including demographic and admission information in addition to CT parameters.[12] More recently, Rotterdam score is valuable for assessing outcomes using head CT findings such as epidural, subdural, and arachnoid lesions, basal cistern effacement, and midline shift.[13]

The extended versions of the CRASH and IMPACT models are among the most notable standard prognostic models, which include individual CT characteristics using different approaches. However, IMPACT Extended score has shown to increase prediction perspectives compared to the conventional parameter approach by including clinical and laboratory parameters such as hypoxia, hypotension, glucose and hemoglobin.[12] We question ourselves whether using multimodal brain monitors, including partial brain tissue oxygen pressure or pressure reactivity index would increment or improve the actual models. Currently, we have studies concerning safety of this usage, but few and low evidence on its association with long-term outcome or prediction.[32,33]

Models that include coagulation parameters have shown better

Table 3
– Favorable neurological functional outcome predictors after critic TBI.

Variable	Coef	SE	Wald	OR	CI (95%)	*p* Value	Adjusted *p* Value[a]
Age	0.078	0.035	5.029	0.863	0.863–0.990	**0.025**	**0.050**
Platelet count	−0.018	0.007	6.271	1.019	1.004–1.033	**0.012**	**0.036**
Hemoglobin	−0.514	0.251	4.199	1.673	1.023–2.736	**0.040**	**0.040**

Coef, Cohen coefficient; SE, standard error; OR, odds ratio; CI, confidence interval.
Bold values indicate potential significant variables.
[a] Method: Holm adjustment.

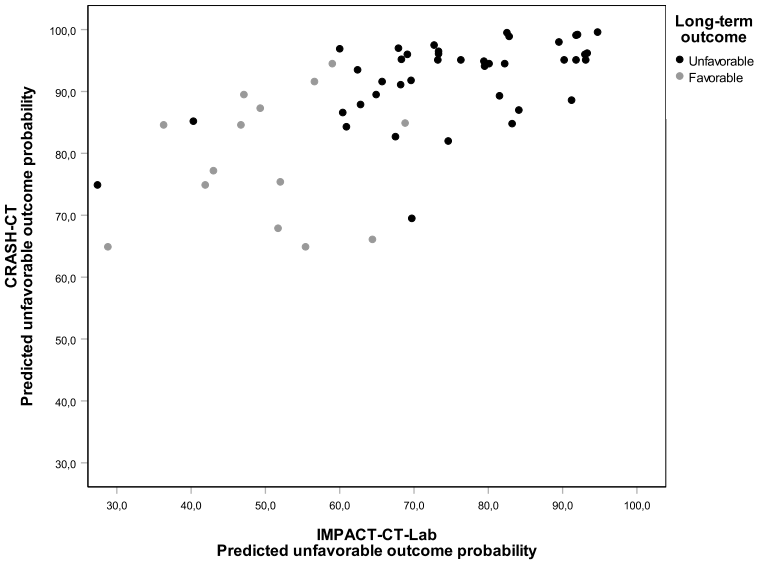

Fig. 2. Predicted outcome probabilities with CRASH-CT and extended IMPACT models.

predictive power when compared to core models.[27,28] However, adding too many variables to a model can complicate its application,[34] and it is essential to carefully evaluate whether adding additional parameters to current standard clinical predictors will improve predictive outcomes, considering the availability of some parameters.[12]

4.4. Recovery and its implications

TBI should not only be considered as an acute condition but also as a chronic disease due to the likelihood of long-term impairments.[5] Cognitive complaints (such as memory, slowness, and concentration deficits), as well as somatic problems such as fatigue, balance, headaches, and other pains, become crucial factors affecting functional recovery, patient quality of life, and the patient's ability to return to work.[7] Therefore, it is important to assess functional recovery in terms of the level of functioning and employability, which can provide higher sensitivity to continued deficits.

Hammond et al reported that although the level of functioning and employability on the DRS represent the primary overall delayed changes, most individual changes do not occur within the second to the fifth years post-injury.[35] This may indicate the importance of post-acute care[36] and first-year post-trauma recovery.[18] However, previous studies have not identified later predictive variables for recovery, as acute care variables such as GCS and pupillary reaction do not seem to predict change for those who survive.[35]

Our findings demonstrate that even patients with GCS scores 3 to 5 can achieve a good recovery and considerable functional improvement over time, indicating that aggressive treatment should be directed towards this patient population. Moreover, attention should be paid from clinicians and from health policies to variables related to outcome through assessment of hemoglobin, platelets, age and the usage of the current predictive models, as these specific patients may obtain more benefits from the directed allocation of medical supplies, including measures for early recovery, possibilities for employment and social reintegration. Additionally, the study sheds light on potential interventions, such as targeted therapies or specialized medical equipment, which can be implemented to optimize recovery outcomes after TBI. This targeted approach not only improves individual patient outcomes but also has broader implications for healthcare resource allocation. This possibility in TBI treatment warrants further investigation.

4.4.1. Limitations

Our study had limitations, including small sample size and retrospective data analysis, which may limit the generalizability of our findings and did not allow us to search for habits or medicines usage, such as DOACs. Regarding binary logistic regression, corrections for testing were not taken into account; also, owing to a small and more heterogeneous sample, we achieved a stable model for multivariate analysis only by the stepwise model (entry forward), whereas IMPACT and CRASH were strong and stable models through the main effects models.

5. Conclusions

Patients with critical severe TBI have poor functional outcomes, with high mortality and disability rates at long-term assessment. Long-term favorable outcomes are related to younger patients and higher hemoglobin levels and platelet counts, which may indicate a subpopulation of patients who may benefit more from early aggressive treatment. Current predictive models for 6-month post-TBI outcomes (mainly IMPACT) appear to predict better long-term outcomes.

CRediT authorship contribution statement

Rubén David dos Reis Zuniga: Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rita de Cássia Almeida Vieira:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Conceptualization. **Davi Jorge Fontoura Solla:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation. **Daniel Agustín Godoy:** Writing – review & editing, Writing – original draft, Methodology. **Angelos Kolias:** Writing – review & editing, Supervision. **Robson Luis Oliveira de Amorim:** Writing – review & editing, Methodology, Data curation. **Almir Ferreira de Andrade:** Writing – review & editing, Supervision, Data curation. **Manoel Jacobsen Teixeira:** Writing – review & editing, Data curation. **Wellingson Silva Paiva:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2024.100361.

Abbreviations list

ABSI - Acquired Brain and Spine Injury
aPTT - Activated Partial Thromboplastin Time
CRASH - Corticosteroid Randomization after Significant Head Injury
CRASH-CT – Extended CRASH model
CI - Confidence Interval
Coef - Cohen Coefficient
CT - Computed Tomography
DRS - Disability Rating Scale
FAPESP - São Paulo Research Foundation
GCS - Glasgow Coma Scale
GOS-E – Extended Glasgow Outcome Scale
ICP - Intracranial Pressure
ICU - Intensive Care Unit
IMPACT - International Mission for Prognosis and Analysis of Clinical Trials
IMPACT-CT-Lab – Extended IMPACT model
INR - International Normalized Ratio
MVC - motor vehicle collision
OR - Odds Ratio
SBP - Systolic Blood Pressure
SE - Standard Error
SpO2 – Blood Oxygen Level
STROBE - Strengthening the Reporting of Observational Studies in Epidemiology
TBI - Traumatic Brain Injury
tSCI - Traumatic Spinal Cord Injury

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